SMU-R-89-125

DEVELOPMENT OF AN INTELLIGENT SEISMIC FACILITY AND PREPARATION FOR PARTICIPATION IN THE CONFERENCE ON DISARMAMENT GROUP OF SCIENTIFIC EXPERTS TECHNICAL TEST

Paul Golden
Eugene T. Herrin

Southern Methodist University
Dallas TX 75275

April 1989

Semi-Annual Technical Report

DEFENSE ADVANCED RESEARCH PROJECTS AGENCY
CONTRACT # MDA 972-88-K-0001

SOUTHERN METHODIST UNIVERSITY DALLAS, TEXAS

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The USGSE network consists of six seismic stations. Four locations in the continental US will be distributed National Data Centers. The NDC's will be located at Dallas, TX; LaJolla, CA; Pinedale, WY; and Blacksburg, VA. NDC central will be located in Washington, DC.

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For the past year, DARPA sponsored research at SMU has been aimed at developing state of the art seismic data acquisition and processing equipment. The Phase II systems developed under this contract are designed to meet all the requirements of the GSE. In addition, SMU is currently planning for the deployment of the next generation NORESS type array, based on the Phase II seismic systems, in Europe T is report contains functional specifications of the data acquisition systems d array controller currently being developed.

Chapter 3 addresses the normal operations of the Lajitas, TX seismic station. During this reporting period many interesting seismic events, including both earthquakes and explosions, have been recorded. We show seismograms of these events with some preliminary analysis.

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INTRODUCTION

This report describes the Southern Methodist University (SMU) involvement in preparations for the U.S. participation in the United Nations Conference on Disarmament Group of Scientific Experts Technical Test 2 (GSETT2) global data exchange experiments, including planning for the USGSE network and progress in the development of the Phase II seismic systems for use in the experiments. In addition we describe progress in the development of the next generation NORESS type array to be deployed in Europe and describe normal operations of the Lajitas, TX seismic station.

The United Nations Conference on Disarmament ad hoc Group of Scientific Experts is planning the next world wide data exchange experiment. For the past year, DARPA-sponsored research at SMU has been aimed at developing state of the art seismic data acquisition and processing equipment so that all countries who want to participate could have access to identical, quality equipment for seismic monitoring. One of the stated goals of the GSE is that all countries have the same capabilities to acquire and rapidly process data for distribution to all other countries, and it is toward this goal that the SMU research effort has been directed.

Initial planning for the GSETT2 has been focused on developing a USGSE network for seismic monitoring. In Chapter 1 we discuss the seismic stations at six sites in the U.S. including Blacksburg VA, Lajitas TX, Pinedale WY, Pinyon Flat CA, North Pole AK, and Maui HA. The four locations receiving data from these sites are considered 'distributed' National Data Centers, with the added responsibilies of operating and maintaining remote field stations. The National Data Center in Washington DC is considered NDC central, and will be responsible for coordinating the efforts of the six stations, quality control of all analysis and operations, and concatenating all GSETT2 parameter and waveform files for distribution to the International Data Centers. In addition, in Chapter 1 we will give a full description of the Lajitas,TX USGSE station including system response, dynamic range, data acquisition and processing techniques, and some noise characteristics.

As previously reported, SMU, in co-operation with Teledyne-Geotech and Science Horizons Inc. has developed the Phase I Intelligent Seismic System. This system has been functioning continuously at the Lajitas seismic station and at SMU for 9 months as of this writing. The Phase I system is composed of Teledyne Geotech field equipment, including seismometers and digitizers and the Science Horizons Inc. data acquisition and processing workstation. Seismic data is relayed from the field station at Lajitas to SMU in Dallas, via a dedicated 56 kbps satellite communications link where it is acquired in near-real time and analyzed. The Phase I system utilizes a simplex SDLC data protocol allowing for a 'listen only' workstation to acquire the data. In addition Phase I systems acquire 6 channels of seismic data using a 24 bit digitizer with resolution dropping to 18 bits at high frequencies (50 Hz.).

In Chapter 2 we include the functional requirements of Phase II systems being developed during this reporting period. These systems are equipped with an extended range digitizer that maintains dynamic range greater than 120 dB over the entire frequency band (up to 60 Hz.). The field system also has 8 additional 16-bit channels for acquisition of ancillary data such as wind speed, wind direction and for system monitoring. Phase II systems also utilize full duplex communications so that the workstation can control the parameters of the field stations remotely. The remote functions include auto or manual calibration capabilities, gain changes, and sample rate changes. Phase II sytems are also capable of broadcasting a simplex data stream via satellite so that other authorized sites could acquire the data without having control capability. Chapter 2 also contains functional specifications of the third generation NORESS type array controller currently being developed.

Chapter 3 addresses the normal operations of the Lajitas, TX seismic station. During this reporting period many interesting seismic events, including both earthquakes and explosions, have been recorded. Seismograms of some selected events are presented with some preliminary analysis.

In summary, this report is comprised of three chapters, chapter one describes the preparation for participation in the United Nations Conference on Disarmament Group of Scientific Experts Technical Test 2 (GSETT2), chapter two contains *functional requirements* of the Phase II seismic systems and the development of the third generation NORESS type array, and chapter three describes normal operations of the Lajitas, TX seismic station and the SMU distributed NDC.

CHAPTER ONE

PREPARATIONS FOR U.S. PARTICIPATION IN GSETT2

GENERAL

During initial planning stages for the GSETT2 experiments it was decided that a distributed National Data Center (NDC) concept would be used. The US NDC functions are distributed among five sites in the continental US. This distributed functionality enables each of the centers to monitor less numbers of national seismic stations so that the analysts have more control over each station and can perform the analysis more accurately and efficiently. Figure 1.1 shows the four sites that actually control stations and perform routine event detection and parameter extraction. These centers are located at Dallas TX, controlling the Lajitas TX national station, Blacksburg VA, controlling the Blacksburg station, LaJolla CA controlling both Pinyon Flat Observatory and the Hawaii National Seismic Station and the fourth installation is at Pinedale WY, controlling Pinedale WY and North Pole AK national seismic stations. The fifth site is NDC central located in Washington DC. This center is in charge of quality control of all stations in the network through analyst review of reported events and also is responsible for proper (GSE controlled) formatting of all parameter files (level I data) and waveform segments (level II data). In addition, NDC central distributes the GSETT2 data to International Data Centers. NDC central also has all of the capabilities of any of the distributed NDC's to acquire and analyze seismic data from additional national seismic stations in the event that more are added to the USGSE network. The USGSE data concentrator facility, located in LaJolla CA, is responsible for continual archiving of all station data broadcast via satellite from each of the six national seismic stations. The NDC central can

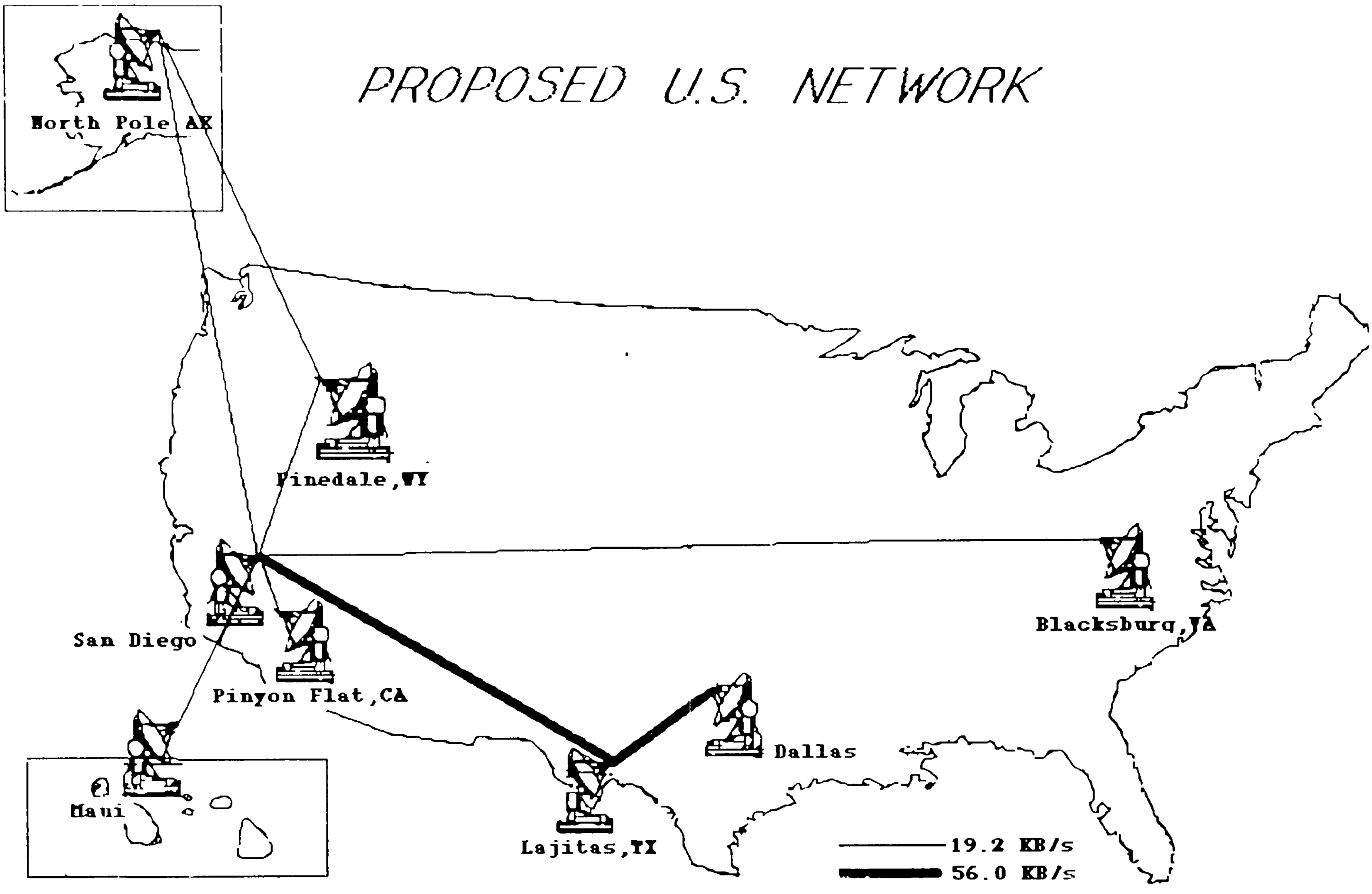

Figure 1.1 USGSE Seismic network

rapidly access the data store via local area network (LAN) in Washington and satellite communication with LaJolla CA.

OPERATIONS

Each of the national seismic stations is identical in their hardware and software to make data analysis as consistent as possible. The seismic sensors consist of three-component short period GS-13 instruments and three component broad-band BB-13 instruments resulting in six channels of seismic data. The combination of the broad-band and short period instruments provides an effective recording band from 100 seconds to 60 Hz if desired. The digitization technique provides up to 24 bits of resolution at low frequencies and always is in excess of 120 dB dynamic range across the entire frequency band, making gain ranging unnecessary. An Omega timing system is used to maintain correct Universal Coordinated Time (UTC) and data is time tagged at the station. Each of the stations are functionally identical to the Lajitas TX station which is described in detail below.

The digital data is transmitted to the NDC either by satellite communication link or cable using the SDLC protocol. At the NDC, the data is acquired by Sun Microsystems-based computers. where continous data is displayed (scrolled in near-real time) on a graphics monitor for quick-look quality control by the analyst. The Op-Z event detector is run on the continual data stream and detected events are segmented into standard CSS 2.8 database event segments, then readied for analysis by an experienced seismic analyst. When the preferred 3-component detector is completed and tested, it will become the standard. At present we prefer to segment the data to include 30 seconds prior to the detected onset of the event and 90 seconds after the detector goes false. This method requires that varying length segments can be handled by all analysis software as is the case. Although this can result in some large segments, we believe it is better to keep more information than we might need instead of throwing some away. Since the continual data streams are acquired and archived at the USGSE data concentrator facility, and NDC central can retrieve the data in a rapid manner upon request, the distributed NDC keeps only one day of continual data at any time, but retains all data segments and subsequent parameters on-line for two weeks. Additional NDC functions include calibration and control of the stations. Remote calibration can be performed either automatically, at a prescribed time, or manually. The preferred method of calibration is manual, due to the fact that during a seismic event, a calibration signal would destroy the event data. Calibration waveforms are treated as events by the detector and are segmented and archived and can be sent to IDC's on request. Control of the station includes remote gain changing and sample rate selection as well as calibration capabilities. Station state of health information and ancillary data, including weather information, is also archived.

Analysis

Routine analysis of the detected events includes selecting the start time of the event and any other phases that can be identified on all three short period channels and then determine the period and amplitude of the first arrival (for calculating magnitudes). This is accomplished with interactive graphics programs for seismic analysis. Each event is displayed on the screen and the detected time is indicated with a tick mark on the seismic trace. The analyst can then position the cursor, with a mouse, to the time of onset he chooses to be most accurate. By pushing a button on the mouse the time selected is displayed on the screen. The amplitude and period of the first arrival is measured in a like manner and also displayed. A pull down menu displays the standard phase names of seismic arrivals and by moving the cursor to the preferred one and pushing a mouse button the analyst can choose the phase he believes the arrival to represent. This technique is followed for any other arrivals (phases) in the event and the analyst can assign a phase name if desired. The analyst can also filter the data during the analysis to improve signal-to-noise and aid in the interpretation of the event. A three pole Butterworth, high pass, low pass, or band-pass filter is available with selectable corner frequencies. The filtering is only for display and analysis purposes and the data-base segment is never changed. The instrument response and nominal calibrations are available in a file so that the ground motion in nanometers is automatically calculated from the digital counts. Also the average ambient background amplitude and period in the 30 seconds. prior to the arrival is estimated by the analyst and is automatically converted from counts to displacement by accessing the calibration file. In addition the analyst measures the azimuth, incidence angle and rectilinearity (degree of polarization) from three component analysis by placing the cursor at the beginning of the event and using another pull-down menu to select particle motion analysis. In the future these parameters should come automatically from the three component detector processing and the analyst could decide whether or not to recalculate the parameters (in case the values seemed intuitively wrong for some reason). Another useful feature would be to display as many of the arrivals (sp vertical only, maybe 15 seconds before and 30 seconds after the detection) on the screen at one time so the analyst could quickly reject the obvious false alarms - after a fast preview of the day another pass could show the remaining events and the analysts could then choose an event to pick parameters on. The addition of an analyst log will aid in determining what procedures were followed to get the results of the analysis session, e.g., filter types used during analysis. This automatic logging has not yet been implemented. After the events are completed (analyzed) they are flagged so that a quick list of the day's events shows whether or not they have all been completed by the analyst.

At the conclusion of the analysis session for each waveform the GSE parameters chosen by the analyst are all displayed on the monitor. The analyst can choose to accept all parameters as displayed and by clicking a mouse button the parameters are formatted automatically in a manner consistent with GSE specifications. At a prearranged time each day, computers at NDC central phone the distributed NDC's and retrieve the parameter files and waveform segments. This is implemented in a shell script that runs each day, currently using the uucp functions of the Unix operating system. This function could also use any of several different communication techniques, including X.25. The NDC central then concatenates all the files and formats them for distribution to the International Data Centers. The USGSE national seismic stations are all identical to the Lajitas TX station, in equipment, and so in the next section we describe the Lajitas station in particular, and the USGSE network in general.

LAJITAS, TEXAS SEISMIC STATION

GENERAL

The station at Lajitas, TX is located at latitude 29.339 degrees north and longitude 103.6669 degrees west. The elevation of the surface vault that contains the seismometers is 1013.5 meters. The station is located on a massive Lower Cretaceous limestone formation. The ambient seismic background is unusually low at this site in the short-period recording band. Short-period data are obtained from three Teledyne-Geotech Model GS-13 seismometers located in the surface vault. Broad-band data are obtained from three Teledyne-Geotech Model BB-13 broad band seismometers colocated with the short period instruments.

DATA ACQUISITION

Data from both short period and broad band channels are currently being sent via a dedicated 56 kbps satellite link to the prototype National Data Center at Southern Methodist University in Dallas TX. Continuous sp and bb data streams are being archived in CSS 2.8 database format at SMU for at least two weeks on-line (disk) for rapid retrieval and on magnetic tape for permanent archive. At this time no detector is used on the data but an assortment of detectors are available, including Op-Z, Walsh and Murdoch-Hutt. The preferred detector for use now is the Op-Z detector, based on modifications to the Gledhill's frequency domain detector (Gledhill, 1985, An earthquake detector employing frequency domain techniques. BSSA, 75,1827-1835), based itself on the earlier Walsh detector.

MODIFIED WALSH DETECTOR (Op-Z)

Short period vertical channels, sampled at 120 Hz are first filtered and decimated to 40 Hz. Successive windows of 3.2 seconds are transformed into the frequency domain, then whitened by multiplying by the inverse of previously determined noise spectra. The whitened spectra is filtered to the expected signal band (usually 1-5 Hz). The log of the total power in the filtered band forms the detection metric. The detection decision is made using simple non-parametric statistics. When the calculated metric exceeds a preset normalized distance from the observed median of previous noise segments, a detection is called.

If a 3.2 second block has no detection, then the calculated spectra are smoothed and averaged into an exponentially weighted noise spectra estimate. Typically, exponential weights are chosen for a 4 minute time constant. The detection metric for this noise block is added to the accumulated distribution of noise blocks and the oldest noise statistic is dropped. This distribution is used in forming the distribution statistics (median and 75 percentile) used for detection. The detector has the following characteristics:

- It is relatively robust, adjusting to various noise conditions to maintain a fairly constant false alarm rate regardless of noise and site conditions.

- The detector is statistically sound. This allows one to quantify expected false alarm rate during lowest noise conditions, allowing a tradeoff between sensitivity and false alarm rate. It also allows us to specify conditions of optimality (in the sense no other detector can do better). This detector is optimum if the noise spectra is stationary and the signal spectra is known. Most of the complications involved in the detector (pre-whitening, non-parametric statistics) are due to approximate these conditions.

The detector is simple and does not attempt any classification of signals. By keeping the filter band liberal, one avoids biasing the detector towards any particular type of signal. Signal classification may thus be performed in a separate step.

In addition, a three-component vector detector, in experimental use now at the SMU NDC, is presumed to be the detector of choice when ready for daily real-time use.

THREE COMPONENT DETECTOR

Current single station seismic detectors are usually restricted to the vertical component only. Occasionally separate voting detectors are run on all three components, but it is rare that the three components are treated as a vector process. A vector detector, using all three components, has two advantages over current single component detectors. First, the vector sum of the three components produces a S/N gain, in much the same manner as multiple array elements. If the noise were equal and uncorrelated on all three a vector detector has a S/N gain of 1.7, which means higher station sensitivity. Second, vector detectors return information about the vector nature of the signal and noise, allowing classification of signals and false alarm management. Detectors may be tuned to take advantage of expected polarization characteristics of seismic signals. All of this is not without cost. The existing implementations of vector detectors are computationally expensive. While it looks possible to implement such schemes on small processors, it will take some clever coding. The detectors are sensitive to changing noise conditions. This can be troublesome during gusting wind conditions when wind direction may be unstable. Also troublesome are small spikes and glitches on the input channels, or spikes in the frequency spectrum. Modern field digitizers should solve the input spike and glitch problem. Spikes in the frequency spectrum from cultural or electrical noise require treatment in the detector.

The current prototype three-component detector has been implemented on three systems for testing, a VAX-750 at SMU, the IBM at NORSAR, and a Sun 3/260 at SMU. Of the three implementions, the VAX-750 version, written in VAX Fortran and AP500 array processor routines, is the most mature and is the only practical implementation for routine processing (it's the only one fast enough to process real time data, and the only one to completely implement noise prewhitening). The IBM version, written in straight Fortran 66, was developed as a proof-of-concept version to compare the three-component detector against conventional beam detectors. The Sun version, written in mixed Fortran, Ratfor, and C, was recently completed as a first step towards implementing the detector as part of the Lajitas prototype station. The current version runs too slow for real time processing, and is being reimplemented in fixed point arithmetic. This is a difficult task, but initial calculations suggest that it should be possible without special purpose hardware.

The current three-component detector consists of three main modules, the signal conditioning module, calculating detection metrics, and the detection decision maker (Figure 1.2). The current detector is designed for high frequency signals only and thus only the short period instruments are used as input to the routine. It also assumes that input instruments are sampled identically (any gain ranging must be synchronized among all of the channels, with all of the channels being sampled at exactly the same

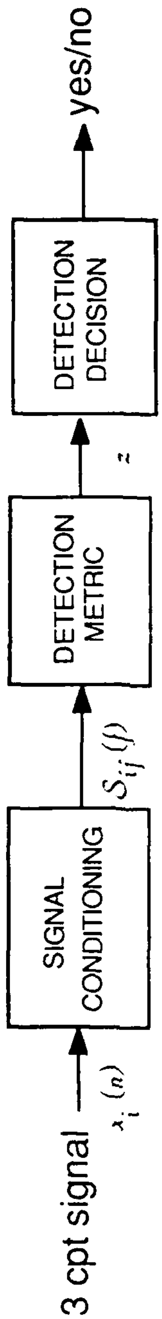

Figure 1.2. The three component detector has three primary modules.

time). Signal conditioning is used to prewhiten all channels in a vector manner to reduce bias problems during spectral calculations. This prewhitened input is used to calculate a detection metric, a single number for each time window estimating the power in the desired signal at that time. For seismic noise, these detection metrics follow some statistical distribution. It is the task of the detector decision module to decide if the current estimate of the detection metric is likely to be noise or signal. Of the three modules, the signal conditioning is both the most complex and compute intensive. Fortunately, most of the operations are well understood and available in standard signal processing libraries. The signal conditioning module accepts the short period signals as input, and produces cross spectra for a requested time window. Operations within the signal conditioning module may be divided into three areas: single component processing, cross-spectra estimation, and cross spectra *whitening* (Figure 1.3). Single component preprocessing, includes deglitching input data, general prewhitening to flatten spectral rolloff, special notch filtering to suppress spectral peaks, windowing and padding for FFT, and finally taking the FFT of the conditioned trace. Of these operations, prewhitening and notch filtering appear to be critical to the success of the detector. The individual FFTs are used to calculate the initial cross spectral estimate. For expected time window sizes (1-2 seconds), this operation is about the same complexity as the FFT on all traces. Finally, it is necessary to prewhiten the cross spectra with previous estimates of noise cross spectra. This is particularily important when the noise is nonwhite in a vector sense (as is most wind noise and cultural noise). Otherwise, not only will detector performance suffer (with high false alarm rates), but also the polarization estimates derived for signals will be biased by noise polarizations. At this point the cross spectra may be saved to use as

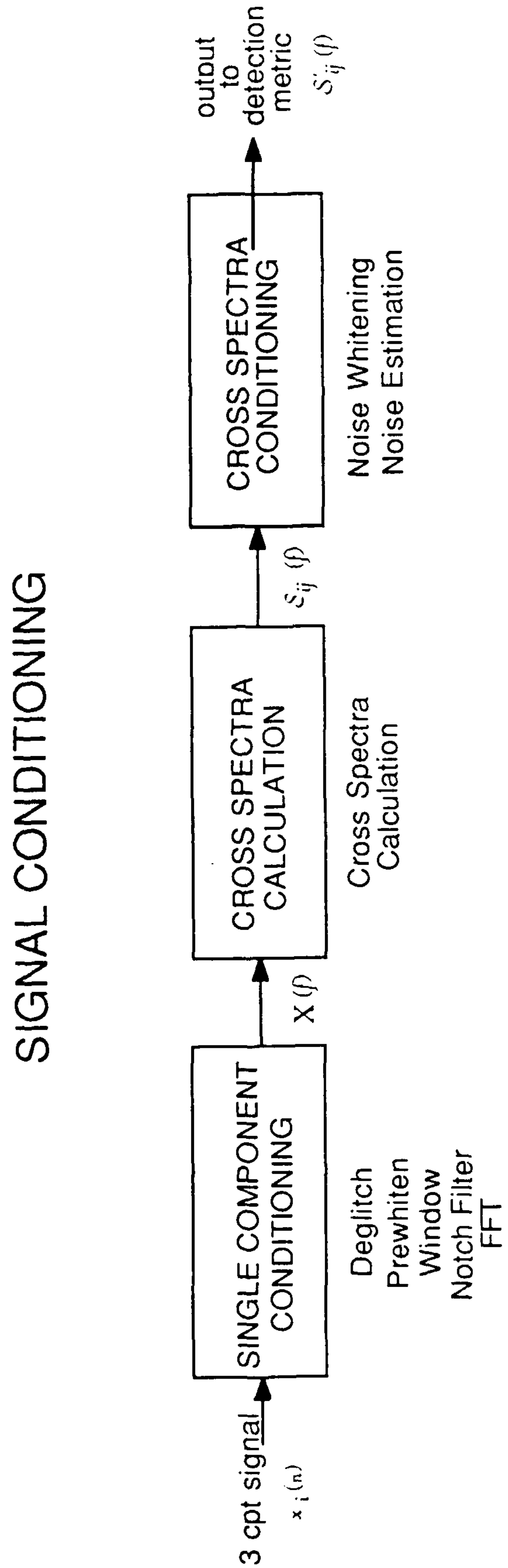

Figure 1.3. The three - component detector signal conditioning modules.

estimates of noise conditions at later times. The fully conditioned signal is used to calculate the detection metric (Figure 1.4). The selected metric (z) estimates the power in dB or the polarized portion of the signal. Beta is an estimate of polarization, while TrS is the total vector power in the three components.

The detector may be preferentially tuned using the polarization exponents, for either a polarization only detector (beta >> 1.0), power sum detector (beta << 1.0), or a combination (beta ~ 1.0). By substituting other measures derived from the cross spectra for beta, metrics may be tuned for a particular polarization (linear, nearly vertical, etc.). Since this calculation is reasonably fast, it is possible to run multiple detectors from the same cross spectra, much as one runs multiple beam detectors on an array. For each detection metric calculated, it is necessary to decide whether that value is likely to represent noise or signal. While it would be desirable to have the noise statistics of the detection metric follow a known distribution, it's not expected except for extremely quiet conditions (where system noise dominates ambient noise). Thus we use a non parametric test based on the median to make the decision (Figure 1.5). A detection is declared if the current value of z exceeds a threshold calculated from the median and the 75 percentiles of z's observed during similar noise conditions. In so far as the tail of the noise distribution is stable, the detector will have a fixed false alarm rate for any particular threshold.

The three component vector detector has been implemented at SMU on the Sun system and is currently being rewritten in order to run more efficiently, in near real time. It is expected to be on-line and fully operational by the beginning of the GSETT2 experiment.

DETECTION METRIC

$z = 10.\ \mathrm{LOG}\ (\beta^{y}\mathrm{TrS})$ where

β is the polarization of S (may have values of 0.0 to 1.0)
y is an exponent chosen by the user (typically 1.2)
TrS is the trace of the cross spectra

Figure 1.4. Detection Metric.

DETECTION DECISION

given: z current metric

z_i a distribution of metrics under noise conditions

Thresh a threshold value

Returns a true / false value

declare detection if $z >$ median + (75% median)Thresh

Figure 1.5. Detection Decision

RESPONSE

System Sensitivities

Nominal system responses, relative to velocity, are shown in Figure 1.6. The SP response is designed to be flat to velocity between 2 Hz and just less than the selected nyquist frequency, in the present configuration 60 Hz. The broad-band acceleration response, also shown in Figure 1.6, is designed to be flat to acceleration from 100 sec. to 5 Hz. Figures 1.7 and 1.8 show the displacement responses, in counts/nanometer of the broad-band (BB-13) and short period (GS-13) channels respectively. In Figure 1.9 we show the relative phase response of the broad band data channels, and Figure 1.10 gives the relative phase response for the short period channels. Calibrated sensitivities to earth motion are as follows:

GS-13 (short-period)	2000 V/m/s at 10 Hz
(broadband)	1000 V/g at 1 Hz
equivalent to:	102 V/m/s^2 at 1 Hz

RDAS Parameters

The fundamental digitizer sensitivities are designed for a full-scale sensitivity of 20 V p-p to produce a full 24-bit digitizer count at a gain of 0 dB. The gain selections, by jumper configuration, are as follows:

GAIN (dB)	FULL-SCALE (V p-p)
10	6.32
20	2.00
30	0.632
40	0.200
50	0.0632
60	0.0200

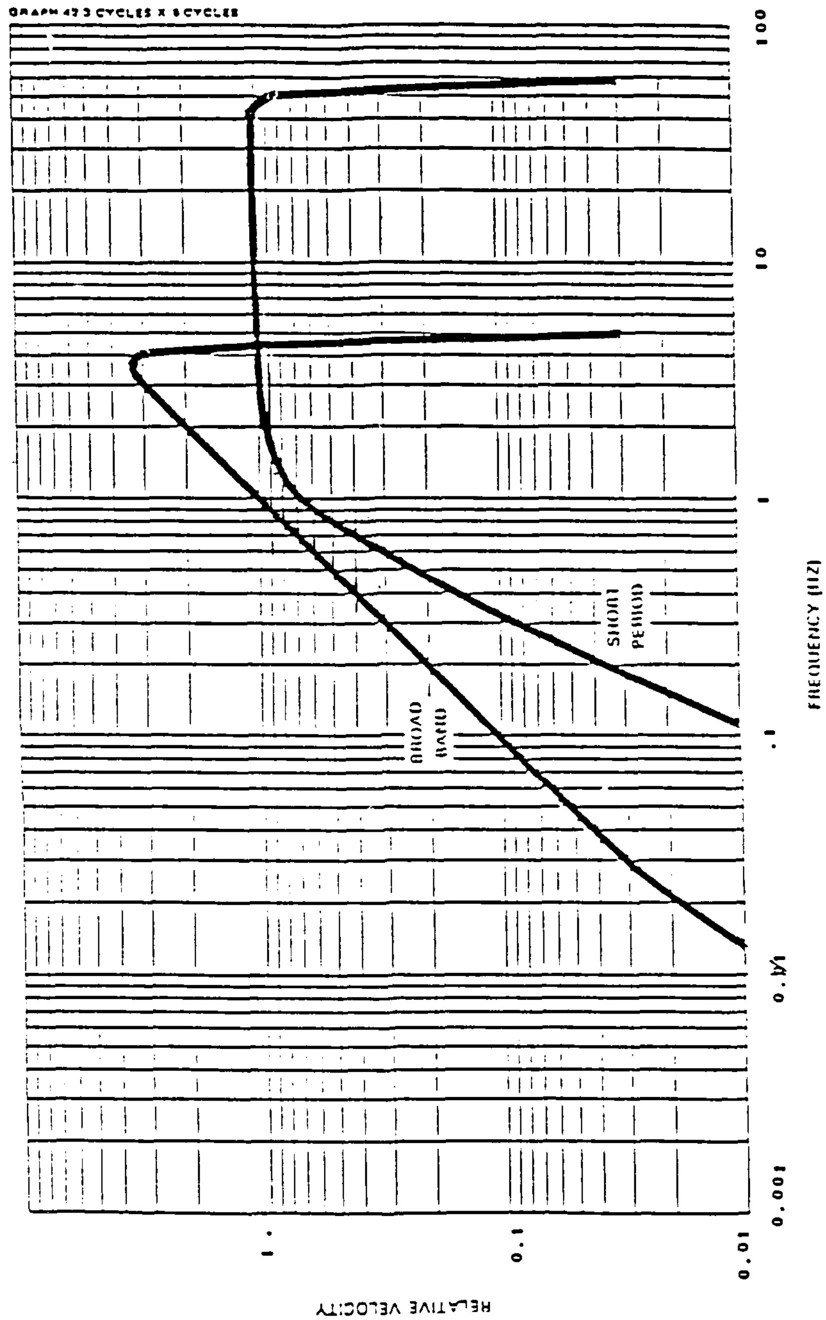

Figure 1.6. Relative instrument responses of broad band and short period channels at Lajitas TX seismic station.

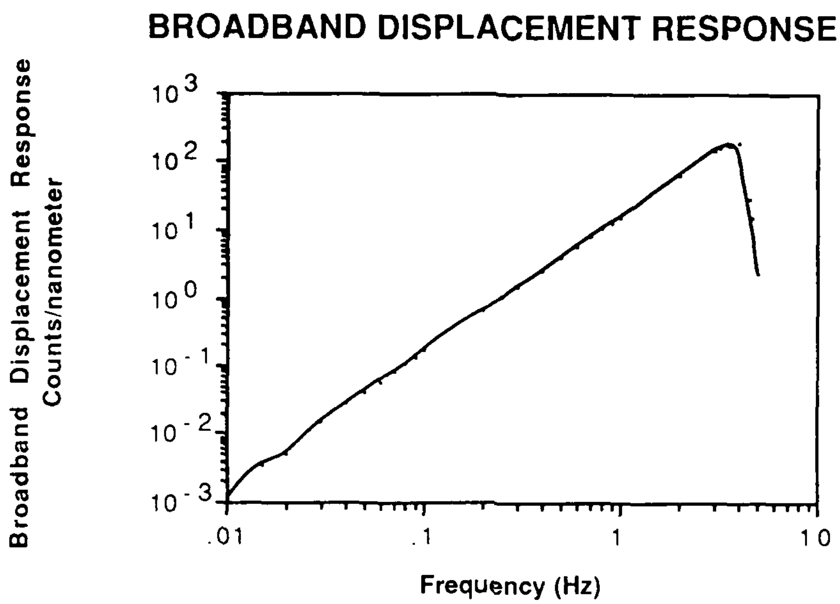

Figure 1.7. Broadband displacement response in counts/nanometer.

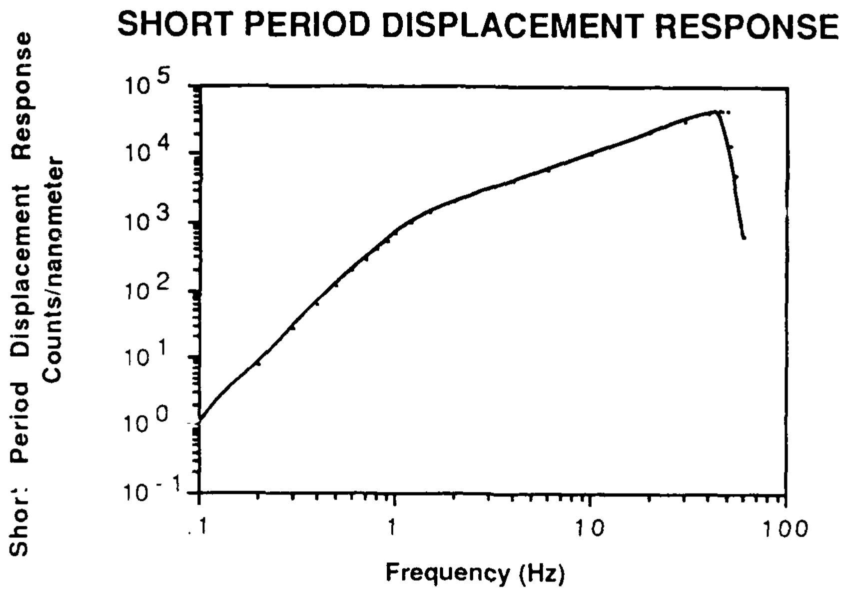

Figure 1.8. Short period displacement response in counts/nanometer.

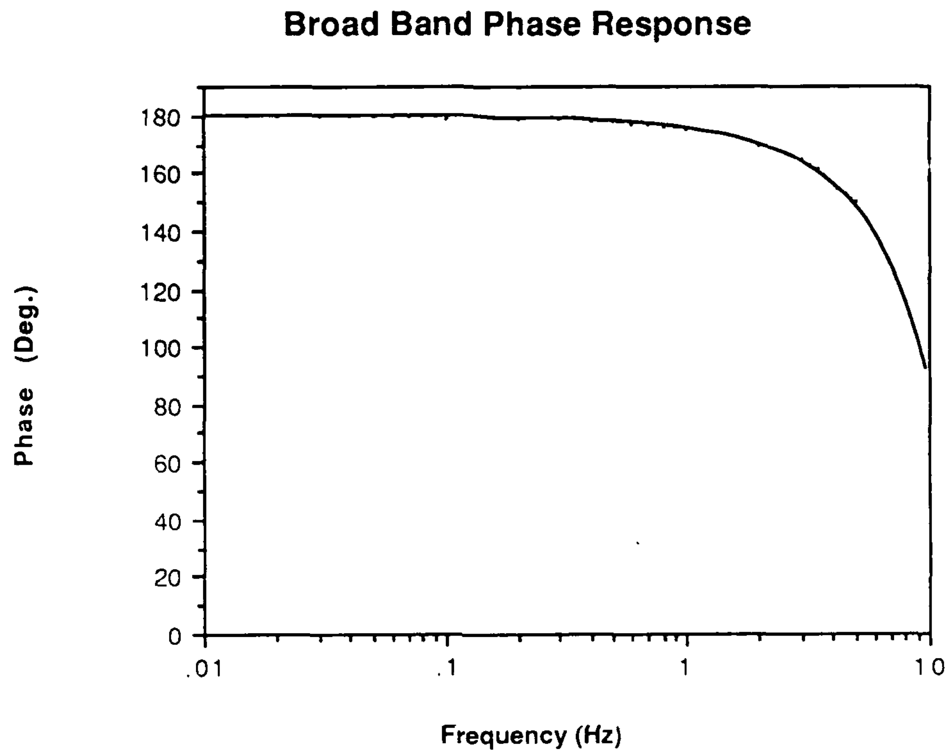

Figure 1.9. Broad band phase response in degrees.

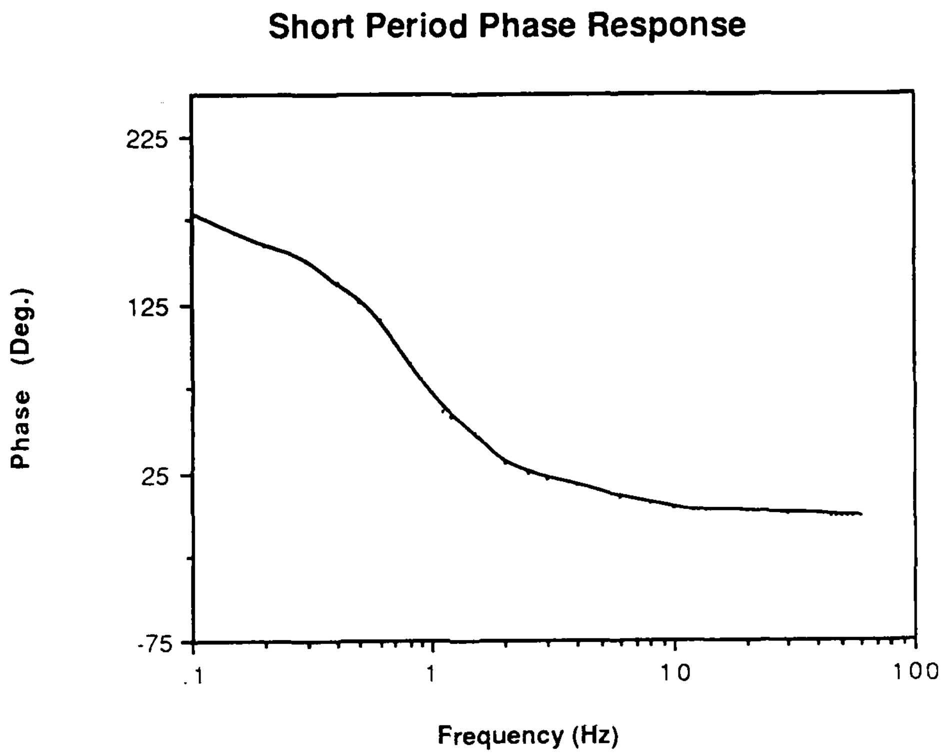

Figure 1.10. Short period phase response in degrees.

The optimum digitizer gains for expected events have been set to 50 dB for GS-13 channels and 30 dB for BB-13 channels. At these gains the nominal calibration values are 167 counts/nanometer/sec at 10 Hz for the sp channels and 2.6 counts/nanometer/s^2 for the bb channels.

We have included a diagram of the Geotech filter design in Figure 1.11 which describes the data over sampling and decimation scheme. The coefficients of the Finite Impulse Response (FIR) filters for various sampling rates are available on request. Frequency, amplitude, and phase triplets for both the broad band and short-period channels are shown in Figures 1.12 and 1.13 respectively and completes the description of the instrument response.

DYNAMIC RANGE AND RESOLUTION

The Teledyne-Geotech extended range digitizer is used in the RDAS200 acquisition system. The digitizer is designed to produce 24 bits of dynamic range across the entire frequency band and in practice produces between 24 and 20 bits dependant on the output sample rate. At 120 sps a minimum of 120 dB resolution is obtained and at 10 sps the full 24 bits is attained. No gain-ranging is applied to the data.

NOISE

The Lajitas station under favorable weather conditions is one of the quietest seismic stations currently operating. Figure 1.14 shows a comparison of minimum ambient noise levels at Lajitas compared to the NORSAR array. Noise levels are generally higher at Lajitas under high wind conditions or during rare rainstorms. The station is currently using a surface vault for the seismometers which also causes higher noise levels. However, in Figures 1.15 through 1.19 we present spectra from five randomly selected sp vertical

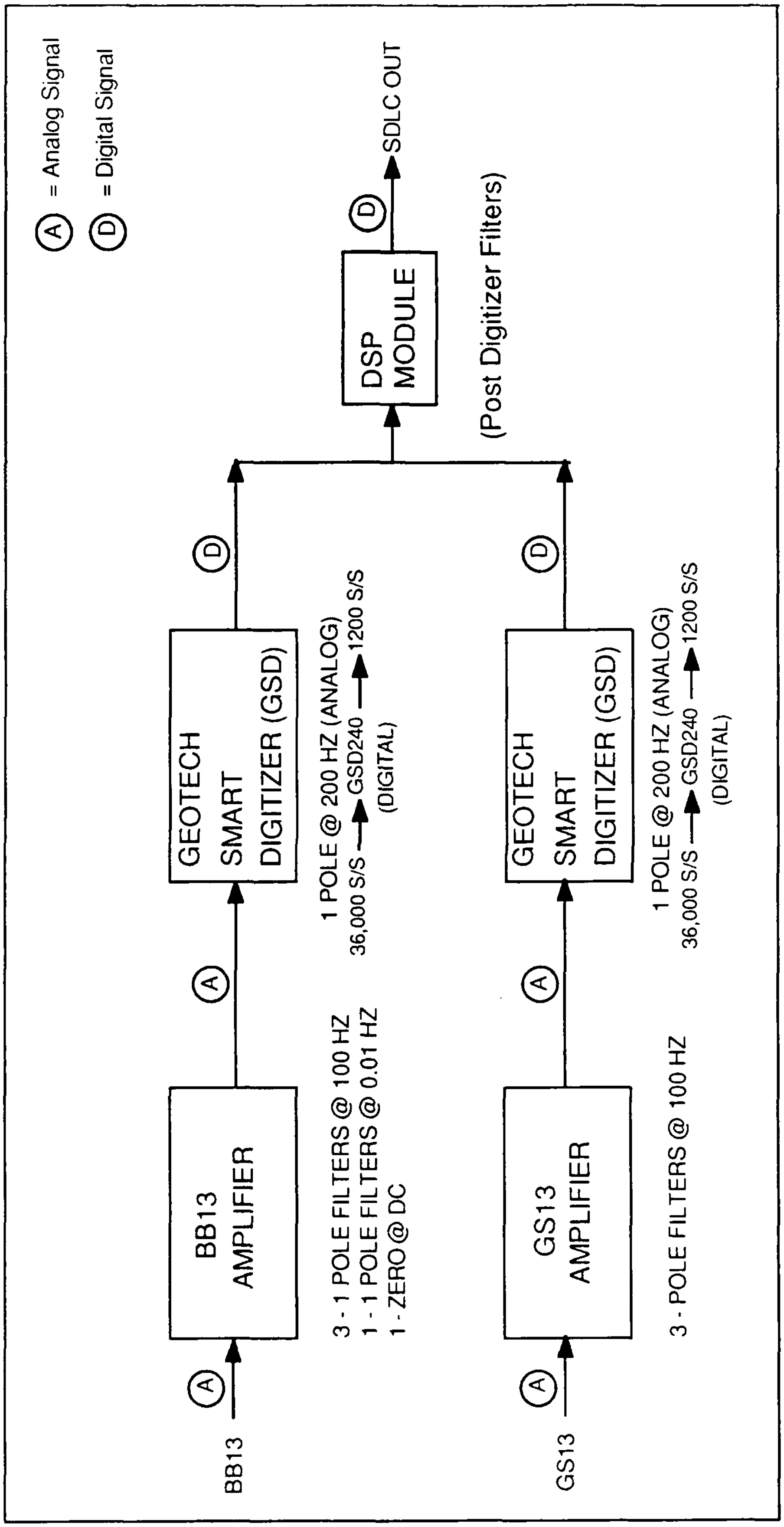

Figure 1.11 Teledyne filter designs for RDAS 200 digital signal processing.

Broad Band Response Data

Frequency (Hz)	Amplitude	Phase (Deg.)
0.010	1.86e-4	180.000
0.015	5.83e-4	180.000
0.020	8.48e-4	180.000
0.030	2.44e-3	180.000
0.040	4.43e-3	180.000
0.050	6.73e-3	180.000
0.060	9.86e-3	180.000
0.070	1.31e-2	180.000
0.080	1.71e-2	179.700
0.090	2.17e-2	179.400
0.100	2.89e-2	179.000
0.200	1.06e-1	179.000
0.300	2.38e-1	178.700
0.400	4.24e-1	178.400
0.500	6.62e-1	178.000
0.600	9.69e-1	177.000
0.700	1.32e+0	177.000
0.800	1.72e+0	176.000
0.900	2.17e+0	176.000
1.000	2.65e+0	175.000
2.000	1.06e+1	170.000
3.000	2.39e+1	165.000
3.200	2.71e+1	163.000
3.500	2.97e+1	161.000
3.700	3.04e+1	159.000
4.000	3.18e+1	157.000
4.200	1.11e+1	155.000
4.500	4.77e+0	153.000
4.700	2.49e+0	151.000
5.000	3.98e-1	150.000

Figure 1.12. Frequency-amplitude-phase response for broad band instruments.

Short Period Response Data

Frequency (Hz)	Amplitude	Phase (Deg.)
0.100	1.52e-1	178.000
0.200	1.25e+0	160.000
0.300	4.32e+0	150.000
0.400	1.02e+1	137.000
0.500	1.86e+1	127.000
0.600	3.10e+1	115.000
0.700	4.74e+1	102.000
0.800	6.78e+1	90.000
0.900	8.85e+1	80.000
1.000	1.14e+2	73.000
1.100	1.49e+2	62.000
1.200	1.67e+2	58.000
1.500	2.29e+2	48.000
2.000	3.23e+2	32.000
2.500	4.24e+2	25.000
3.000	5.07e+2	22.000
4.000	6.78e+2	18.000
6.000	1.02e+3	10.000
8.000	1.36e+3	7.000
10.000	1.69e+3	4.000
20.000	3.39e+3	2.000
30.000	5.08e+3	1.000
40.000	6.78e+3	0.500
42.000	6.90e+3	0.400
45.000	7.02e+3	0.250
47.000	7.17e+3	0.200
50.000	7.37e+3	0.200
52.000	2.20e+3	0.150
55.000	8.39e+3	0.100
60.000	1.02e+2	0.000

Figure 1.13. Frequency-amplitude-phase response for short period instruments.

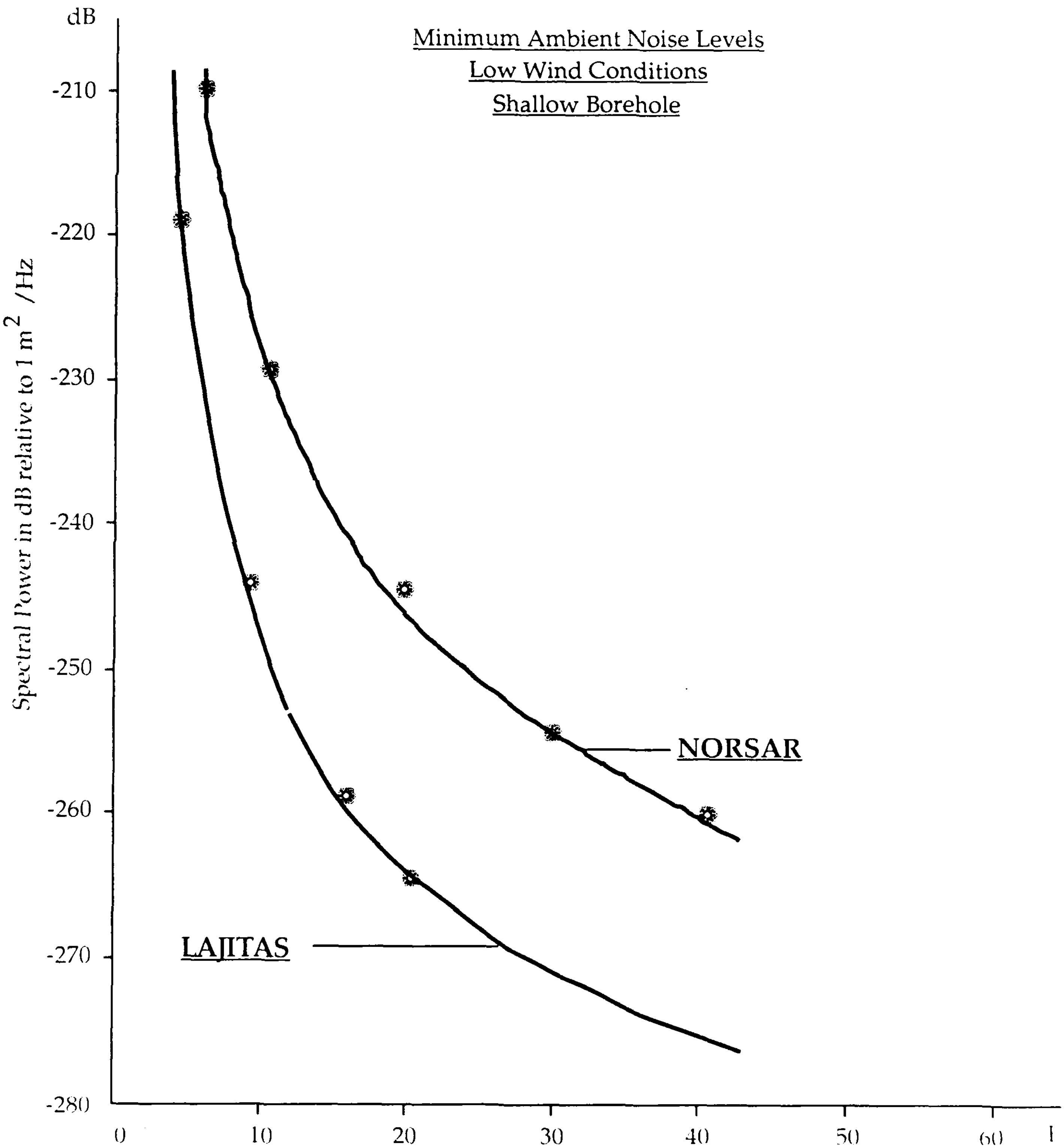

Figure 1.14 Comparison of ambient noise at Lajitas TX and NORSAR array

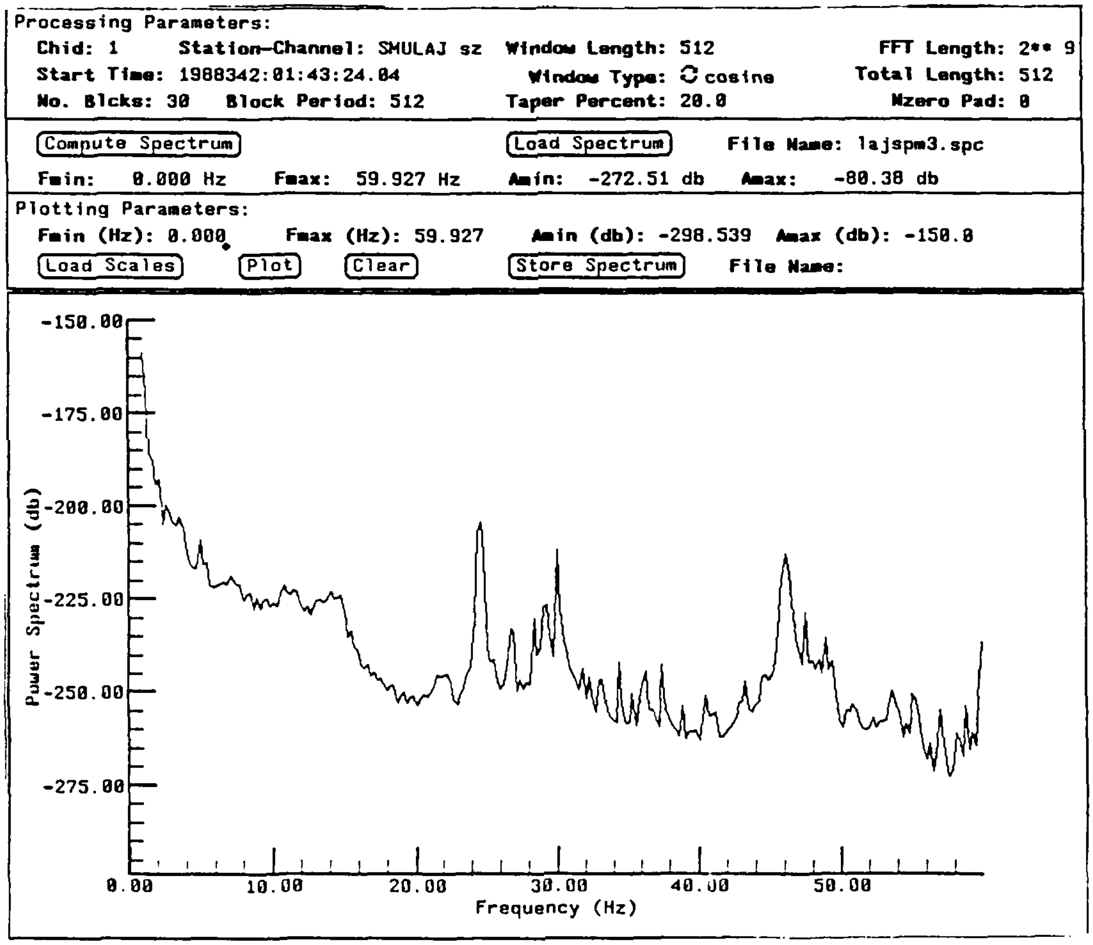

Figure 1.15. Block averaged spectrum of ambient background noise at Lajitas TX.

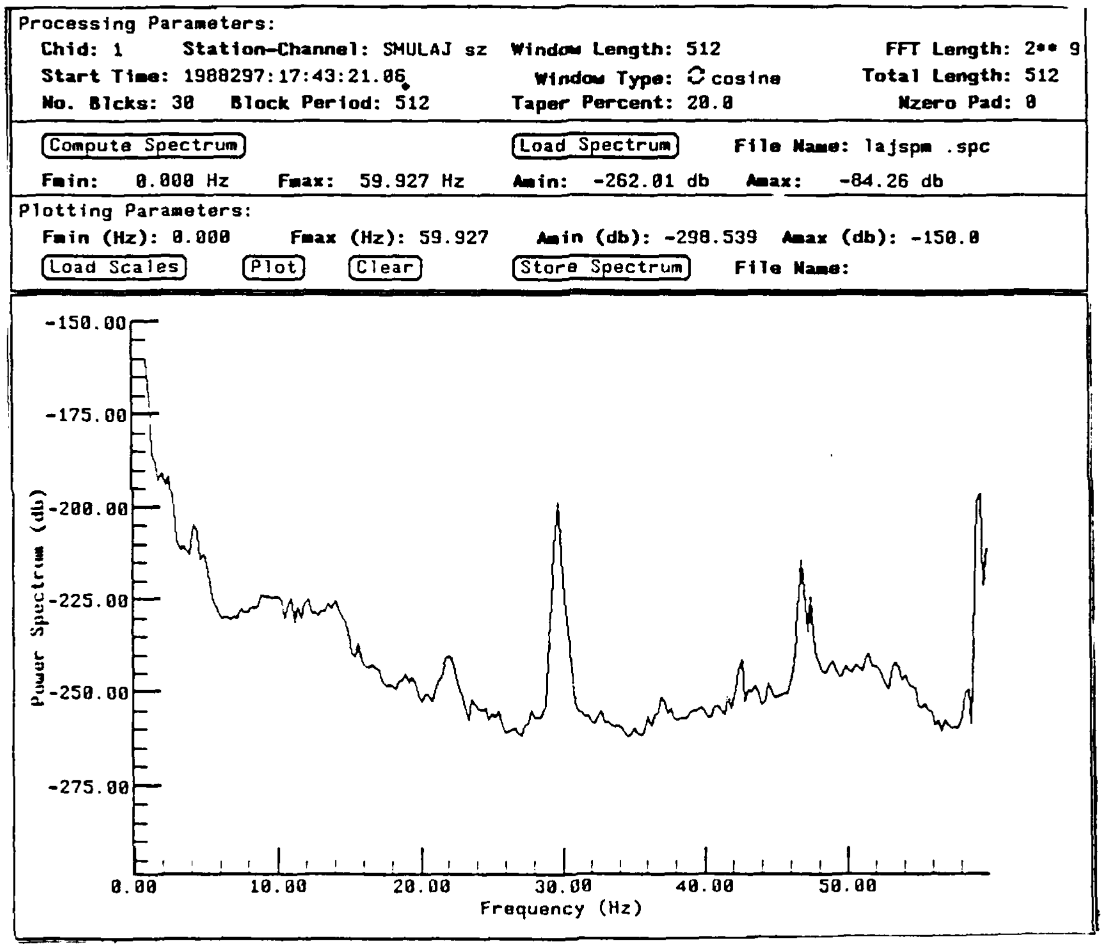

Figure 1.16. Block averaged spectrum of ambient background noise at Lajitas TX.

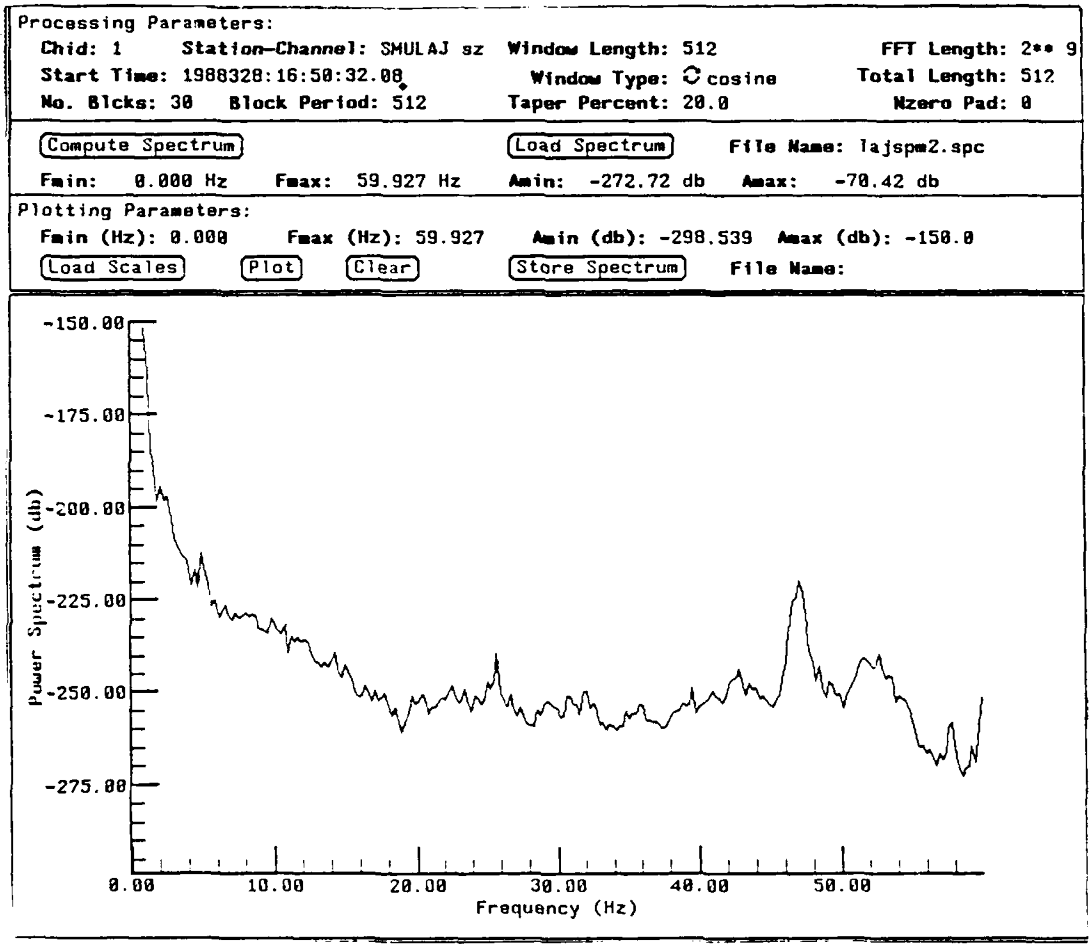

Figure 1.17. Block averaged spectrum of ambient background noise at Lajitas TX.

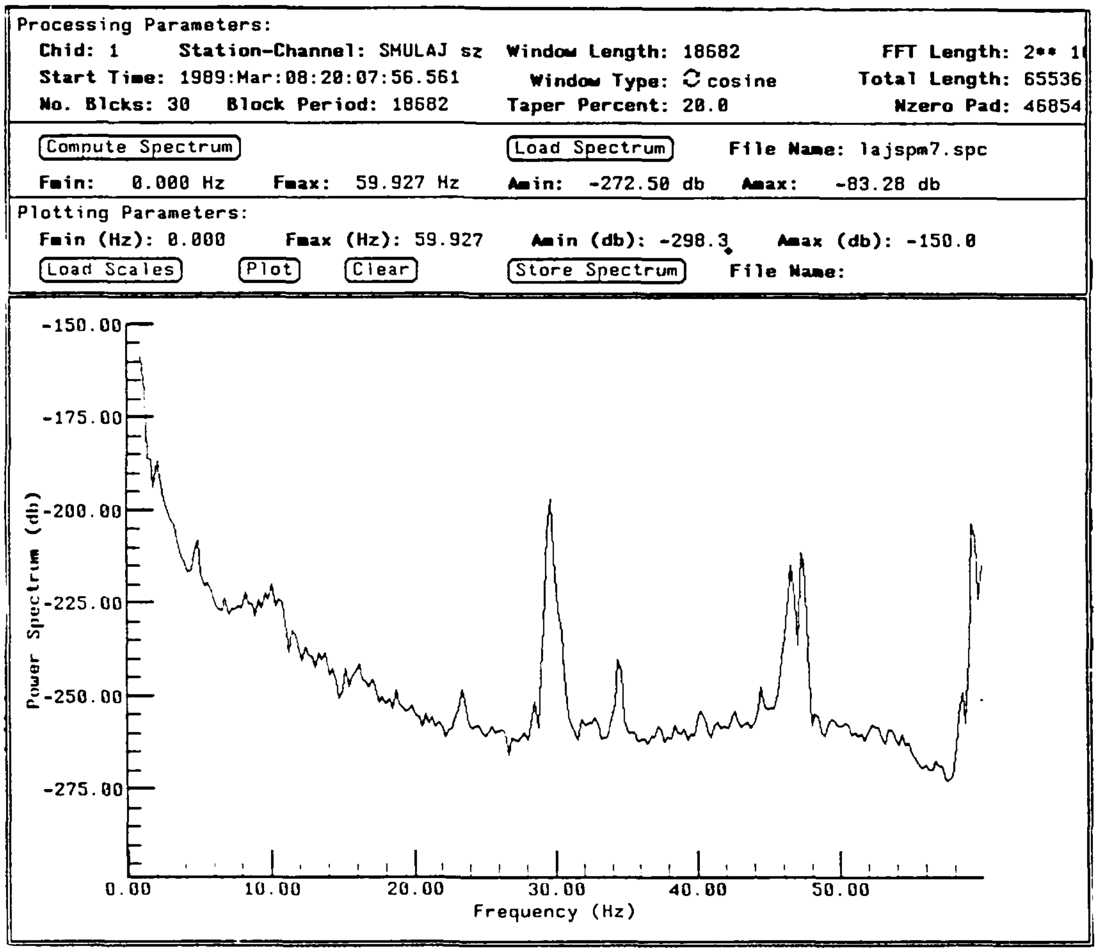

Figure 1.18. Block averaged spectrum of ambient background noise at Lajitas TX.

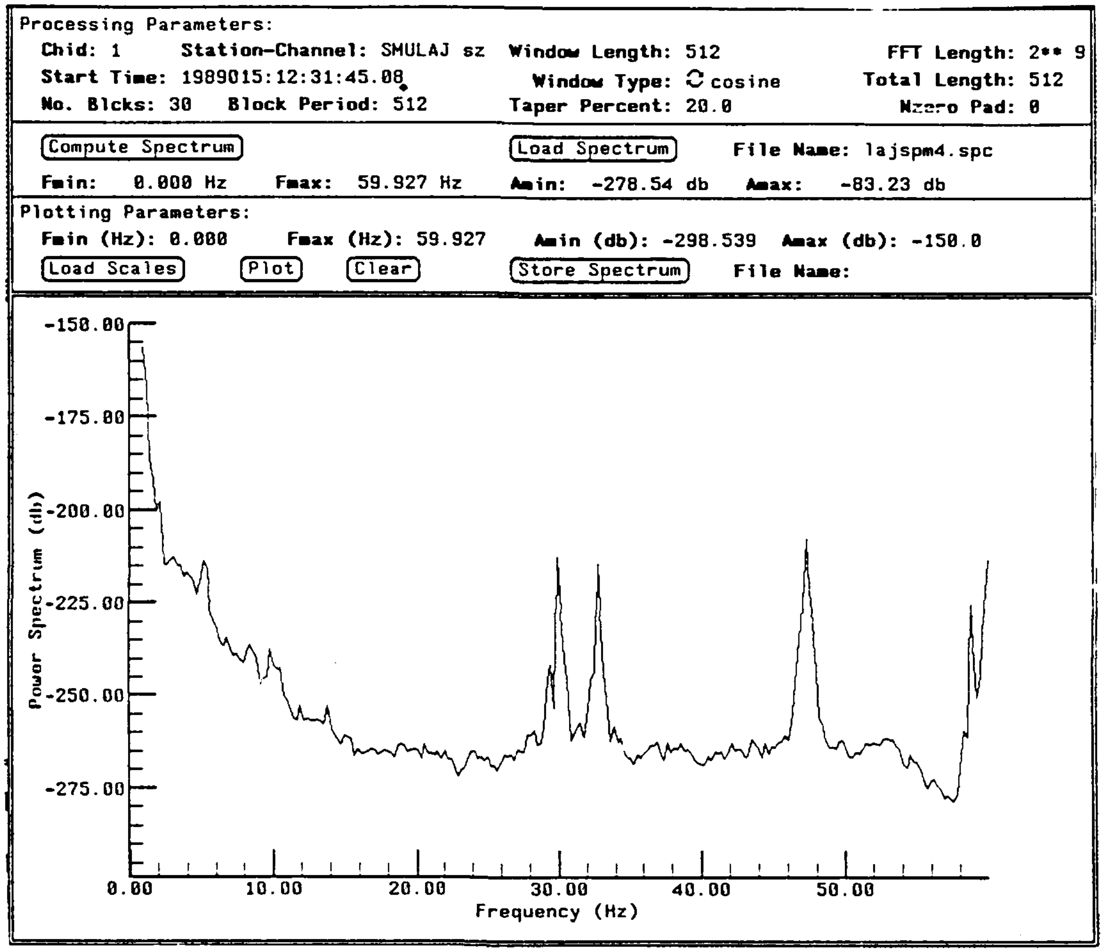

Figure 1.19. Block averaged spectrum of ambient background noise at Lajitas TX.

channel data segments. The data shows both high noise conditions (Figure 1.15) and fairly quiet Lajitas background (Figure 1.19). The noise spectra in Figure 1.19 illustrates that at 10 Hz the quietest background level is approximately -245 dB re m^2/Hz for comparison with Figure 1.14. The quietest level at 20 Hz is -265 dB re m^2/Hz which is approximately the same as the projected value from Figure 1.14. The spectral peaks around 30 Hz are caused by equipment at the site that is normally turned off when the site is unoccupied. The additional peaks above 30 Hz are believed to be caused by cultural objects at the site (buildings, telephone and power poles ,etc.) under high wind conditions.

Preparations for U.S. participation in the GSETT2 global data exchange experiment are well under way at SMU, with the completion of the Phase I seismic systems and the prototype Phase II systems being tested. In addition, sytem planning, preliminary site surveys, and civil work planning for the USGSE network are continuing on schedule. Implementation of the three component vector detector is planned to be well in advance of the beginning of GSETT2 in order to properly test it. The Lajitas station has been fully described thereby describing all USGSE network stations. In Chapter 2 we present the functional requirements of the Phase II systems as provided by Teledyne Geotech, as part of the systems documentation required. In addition, functional requirements of the third generation NORESS type array are given. As these are working documents, some of the specifications are still to be determined and are stated as TBD in the descriptions. Preliminary planning for the deployment of the array in Europe has begun and will be discussed in future reports.

CHAPTER TWO

PRELIMINARY SPECIFICATIONS
REMOTE DATA ACQUISITION SYSTEM RDAS-200 - Model 1

GENERAL

INTRODUCTION

The Remote Data Acquisition System 200 (RDAS-200) is a low powered, continuous-data, data acquisition system. This specification covers the RDAS-200 Model 1 and any place where RDAS-200 is used refers to the Model 1 version. The RDAS-200 has been designed around the PDAS-100 (IBM Personal Computer) architecture, allowing a modular approach to both hardware and software. Functionally, the RDAS-200 is an IBM PC-compatible computer without a keyboard or monitor. The RDAS-200 is a variation of the Teledyne Geotech RDAS-100 that includes an enhanced wide range digitizer, duplex uplink communications, sensor calibration capability, and synchronized digitization. During configuration and setup, the RDAS-200 is designed to accept commands via high-speed link(s) from a co-located Portable Setup and Analysis Computer (a battery powered, IBM compatible laptop computer, the Teledyne Geotech PSAC-100) or from a remotely located work station. The RDAS-200 is designed to transfer data via a high-speed SDLC formatted data link to a remotely located workstation.

SCOPE

This specification is a working document and will be used to communicate design goals and coordinate the design effort. As a working document, the specification will be revised as required during the design effort; however, it is and will remain consistent with advertised descriptions of the Inteleseis equipment. Specification revision will be under control of the Project Engineer subject to the approval of the Program Manager. An "as built" final version of the document will be prepared upon completion of the project. The date at the top of the first page of any copy of the specification will be the revision date of that copy.

APPLICABLE SECTIONS

The following sections are directly referenced by, and are applicable to, this specification to the extent listed herein. IAC - RDAS-200 Host to RDAS-200 Interface Control.

DESCRIPTION

The RDAS-200 is a remote data acquisition system that collects and time tags data *from attached seismometers* *then transmits* these data to a host computer. The RDAS-200 accepts commands from the host for setup and control the remote data acquisition system. This document covers the format of the ADCCP Address and Information fields.

FUNCTIONAL REQUIREMENTS

DATA INPUT

The RDAS-200 shall be available with from one to six primary data channel and with 8 auxiliary input channels. The primary data channel inputs shall have differential-input, low noise preamplifiers and input transient protection. The primary data channels shall provide 24-bit data samples with a sample rates up to 120 samples-per-second-per-channel. The auxiliary input channels shall have a resolution of at least 16-bits.

DIGITAL SIGNAL PROCESSING

An oversampling technique shall be employed whereby the analog-to-digital conversion of each primary data channel shall occur at a rate higher than the recorded/transmitted rate for that channel. This oversampling shall facilitate the operation of a Digital Signal Processor (DSP). The DSP shall perform sample rate decimation and digital anti-alias filtering. Linear-phase digital filters (finite impulse response) shall be used.

DATA STORAGE MODULE

The RDAS-200 shall include up to 12 megabytes of CMOS static random access memory (RAM). The RAM shall contain on-board batteries that provide data retention for a nominal period of two years in the absence of primary power. The data storage RAM shall be utilized so that the most recent data files are retained in the RDAS-200.

DATA ACQUISITION AND PROCESSING

The RDAS-200 shall be capable of transmitting all acquired data in near real time to a remotely located control and recording device (CRD) thru an SDLC-compatible I/O port. It shall also be possible to transmit selected data from the RDAS-200 while continuing to acquire and transmit data in near real time. It shall be possible to transfer selected data files out of the RDAS-200 in an off-line mode using a PSAC-100. The CRD is typified by the Inteleseis Work Station.

SENSOR CALIBRATION

The RDAS-200 shall be capable of providing a calibration signal to any subset of sensors connected to the unit. The RDAS-200 shall be capable of providing a calibration signal of any one of three types; sine wave, pseudo-random noise, and pulse.

SYSTEM CLOCK

Incorporated in the RDAS-200 shall be a system clock. Once an external time source is connected to the RDAS-200, it shall be possible to command the RDAS-200 to synchronize to the external time source, and the rate of synchronization slew shall be programmable. Once synchronized, the RDAS-200 shall remain synchronized to the external reference utilizing a continuous adjustment technique to preclude addition of noise to the data as a result of discrete changes in timing.

POWER SOURCE OPTIONS

External power source options shall include 110 vac at 60Hz, 220 vac at 50Hz, and 12 vdc. The RDAS-200 shall contain a built-in battery charger that can be continuously connected to the external battery for charging.

PACKAGING

The RDAS-200 enclosure shall be designed to withstand the rigors of typical field deployments. The electronics card cage(s) shall be fastened to the mounting plate of a NEMA-12 enclosure such that the plug-in modules are easily accessible when the enclosure door is open. Weather resistant connectors shall be utilized for all external terminations. In addition, two connectors shall be provided for the battery power source so that the batteries can be changed without powering down the unit.

REQUIREMENTS

OPERATIONAL

The RDAS-200 shall be capable of operating in two basic modes. These modes are acquisition and transfer. Mode selection shall be accomplished by commands entered locally by the PSAC-100 or remotely from the CRD.

Acquisition Mode

In the acquisition mode, the RDAS-200 shall automatically and continuously acquire, digitize, time tag, format, and output data thru the SDLC communication port. The time tagged digital data shall be stored so that the most recent data will be in the RDAS-200 at any time during the acquisition process. The RDAS-200 shall be capable of transmitting selected files of previously acquired and stored data when so requested by the CRD. Upon termination of the acquisition process, the most recently acquired data shall be retained for possible transfer to the PSAC-100 (see section 3.1.2). Initiation and termination of acquisition mode operation shall be accomplished by commands from the CRD or a PSAC-100.

Transfer Mode

The transfer mode shall be an off-line mode of operation. In the transfer mode, it shall be possible to copy RDAS-200 data file(s) to the PSAC-100 The transfer of data from the RDAS-200 to the PSAC-100 shall leave the data in the RDAS-200 intact. Initiation of the transfer operation shall be possible with an RDAS-200 for which an orderly cessation of operation in transmission mode has previously occurred, ie., an idle RDAS-200. A visual indication of the success of a transfer (successful or unsuccessful) shall be presented to the operator upon completion of the transfer operation. Initiation and any other control commands for the transfer mode shall be accomplished with the CRD or the PSAC-100.

PERFORMANCE

Analog Inputs

Primary Data Channels

The RDAS-200 shall be configurable with from one to six primary data channels.

Input Characteristics

The nominal input impedance of each RDAS-200 data channel shall be 4 kohms which will require a source impedance of 100 ohms, and each input shall be balanced-differential with a common rejection of at least TBD at 1 Hz and TBD at 50 and 60 Hz. Provision shall be made for attachment of a damping impedance for each of the primary data channels.

FREQUENCY RESPONSE

The frequency response of the primary data channels shall be effectively programmable and determined during RDAS-200 configuration by the CRD or the PSAC-100. The low-pass cutoff frequency shall be determined by being nominally related to the sample rates specified previously by the expression (cut-off) = 0.8 X (sample rate). The high-pass cutoff frequency shall be 0.003 Hz.

SAMPLE RATE

The sample rate of each channel shall be selectable independently of the rates selected for the other channels. The available rates shall include but not be necessarily limited to 120, 100, 80, 60, 50, 40, 20, 10, 5, 2, and 1 samples-per-second.

RESOLUTION

The digitizer for each primary data channel shall output 24-bit (minimum) values for each sample. The nominal resolution of each digitizer within the passband 0.003 to 50 Hz is TBD, and the nominal resolution within the passband 0.003 to 4 Hz is TBD.

Signal Range

The RDAS-200 shall automatically accommodate a signal range of at least 2**24 (144 dB).

Modulation Products

The modulation products of the digitization process shall be TBD dB referenced to full scale.

Non-Linearity

The digitizer non-linearity shall not exceed TBD %.

AUXILIARY ANALOG INPUT CHANNELS

As an option, the RDAS-200 shall include 7 auxiliary input channels. Each of these channels shall have a resolution of at least 12 bits. The full scale range of the auxiliary input channels shall be plus and minus 10 volts full scale.

Status Inputs

The RDAS-200 shall include the optional capability for 8 digital inputs.

TIME

The RDAS shall generate data frames (see section 3.2.4). Each data frame shall be time tagged with time based on the time-of-day input to the RDAS-200: (1) by the PSAC-100 during initialization or the CRD during initialization or subsequent time-of-day updates (without interrupting data acquisition), or (2) automatically from a colocated Kinemetrics Omega Receiver (or equivalent).

BACKUP DATA STORAGE

The RDAS-200 shall be designed so that up to four 3-megabyte non-volatile RAM modules can be included in the system for the system RAM and backup data storage. The basic system shall be supplied with one and one half megabytes of non-volatile RAM.

COMMUNICATION INTERFACE

The RDAS-200 shall output data to the CRD thru a duplex serial port. The data shall be output from the RDAS-200 to the CRD in a format compatible with that of the SDLC protocol. The transmit communication link shall operate at a speed between 1200 bits/second and 200 kbits/second. The transmit rate shall be controlled by a common or independent externally supplied clock source(s). Each data block shall include a header followed by a block of data containing one second of data. This header shall include the type information, time tag for that block, clock status, channel number, sample rate index, and state of health status. The data message format shall be as defined in the Host to RDAS-200 Interface Control Document, IAC - RDAS-200. Command messages from the CRD to the RDAS-200 shall be in an SDLC-compatible format. The RDAS-200 receive circuit shall operate a a speed between 1200 bits/second and 200 kbits/second. The receive rate shall be controlled by a common or independent externally supplied clock source(s). The set of commands that the RDAS-200 shall accept from a CRD is listed in table 1. The command message format shall be as defined in the Host to RDAS-200 Interface Control Document, IAC - RDAS-200.

CALIBRATION SUPPORT

The RDAS-200 shall provide calibration for the sensors connected to the primary data channel inputs. In response to a command from the CRD, the RDAS-200 shall output a calibration signal to any subset of sensors connected to the RDAS-200. The calibration signal shall be selectable as a sine-wave, pseudo-random noise, and pulse. The calibration command message will include start and stop times and the RDAS-200 shall output calibration signals during the time interval defined by the start and stop times. The frequencies available for the sine-wave shall range from .001 thru 500 Hz. The calibration signal amplitudes are selectable within the range of 0 to 4500 millivolts. The impedance of the calibration output ports is nominally TBD ohms.

POWER REQUIREMENTS

The RDAS-100 shall be capable of operating from a nominal 12 Vdc scurce or from a nominal 110/220 Vac, 50/60 HZ source. When primary power is obtained from an ac source, the RDAS-100 shall utilize an internal battery charger and an external 12 volt battery. Power consumption from a 12 Vdc source shall not exceed TBD watts, and power consumption from a 110/220 Vac source shall not exceed TBD VA, including power required for the battery charger.

PHYSICAL CHARACTERISTICS

General

The RDAS-200 shall be contained in a NEMA-12 enclosure. This enclosure shall allow wall mounting using enclosure mounting flanges at the top and bottom of the enclosure. The RDAS-200 shall utilize external 12 volt batteries to prevent hydrogen build-up within the unit in the event of charger or battery failure.

Size

The nominal size of the RDAS-200 shall be 24 inches wide by 30 inches high by 12 inches deep when mounted on a wall using the NEMA-12 mounting flanges.

Weight

The nominal weight of the RDAS-200 shall be TBD pounds, excluding batteries, when crated for shipment.

Termination Requirements

Unless otherwise noted, the physical termination of each interface described shall be a "Bendix type PT" bulkhead connector. All connectors shall be mounted on the bottom side of the NEMA-12 enclosure. Each connector shall contain the signals and perform the functions described below.

Control And Recording Interface

A single connector shall be provided for the SDLC port described in sections 2.4 and 3.1. The output levels shall be compatible with the RS-422 standard.

Sensor Interfaces

An individual connector shall be provided for each of the six sensors. Each connector shall contain the data and calibration pairs required for the seismometer that will be connected to that connector. Each sensor connector shall contain power conductors for the preamplifilers associated with the sensor serviced by that connector. In addition, the connectors for the BB sensors shall include power conductors for the sensors.

Auxilary Input

An individual connector shall be provided for the eight auxilary analog inputs. This connector shall contain the data inputs for each auxilary input.

PSAC Interface

Two PSAC-100 interface connectors shall be provided for this interface. The first of these connectors shall be an RS-232C signal-compatible connector. This connectors shall provide local PSAC-100 access to the RS-232 port to allow local control of the RDAS-200 by a PSAC-100 at the RDAS-200 location.

Similarly, an IBM PC parallel-port signal-compatible connector shall be provided. This connector shall be used to transfer data between the RDAS-200 and a co-located PSAC-100.

Status Input Interface

An individual connector shall be provided for the eight status digital inputs. Status input levels shall be TTL level compatible.

Primary Power Interface

A connector shall be provided for primary power. This connector shall provide power and ground termination as required. An enclosure-external power cable shall be provided that is compatible with the Primary Power Interface connector (RDAS-200 end) and with the local service (service end). *This cable shall be at least ten feet long.*

Battery Interface

Two parallel connectors shall be provided that allow an external batteries to be connected to the internal RDAS-200 battery charger.

Ground

The RDAS-200 shall include a common ground to which the return lead of major internal power, signal, and data busses are connected. It shall be possible to connect one end of a no. 12 AWG conductor to this common ground and connect the other end of the conductor to a point external to the RDAS-200. The low side of the primary power input (section 3.2.7.2.4) shall be connected to the RDAS-200 common ground.

Transient Protection

Transient protection shall be provided for the SDLC interface described previously. Transient protection shall be provided for the high side of the primary power input.

Environmental Characteristics

Operating Temperature

The operating temperature range of the RDAS-200 shall be -20 deg C to +50 deg C.

Storage Temperature

The storage temperature range of the RDAS-200 is -55 deg C to +85 deg C.

Humidity

The operating and storage ranges for relative humidity are 5 to 95 percent, non-condensing.

Table 1. RDAS-200 Command Set

CAL (Calibration)

The CAL command shall cause the RDAS-200 to run a calibration test on a selected channel using the user selected signal parameters.

TIMEREAD

The TIMEREAD command shall cause the RDAS-200 to read its internal time and to read time from the synchronous clock and transmit it to the remote work station.

TIMESET

The TIMESET command shall cause the array element to set its time to the time received from the remote workstation or from the synchronous clock if the data field is set to all zero's.

SUSPEND

The SUSPEND command shall cause the RDAS-200 to suspend transmission of data to the remote workstation for the selected channel.

RESUME

The RESUME command shall cause the RDAS-200 to resume transmission of data to the remote workstation for the selected channel.

RATESET

The RATESET command shall cause the sample rate for the selected channel to be changed to the sample rate sent with this command.

Table 1. RDAS 200 Command set.

(Continued)

REINIT

The REINIT command shall cause the RDAS-200 to reset to its initial operating state which shall include setting all operational parameters to their default values.

REXMIT

The REXMIT command shall cause the RDAS-200 to retransmit a set of selected data that had been previously collected to the remote workstation.

CONFIG

The CONFIG command shall cause the RDAS-200 to transfer configuration information data to the remote workstation which shall include system configuration information and channels 1 thru 6 information.

HEALTH

The HEALTH command shall cause the RDAS-200 to transmit state of health status for the RDAS-200 to the remote workstation.

PRELIMINARY SPECIFICATION INTELESEIS ARRAY CONTROLLER (IAC)

GENERAL

INTRODUCTION

The Inteleseis Array Controller (IAC) is a multi-element array controller, which has been designed around the IBM AT Personal Computer architecture allowing a modular, high-level approach to both hardware and software. The IAC continuously acquires data from array elements, optionally stores that data on 8mm tapes, sends commands and receives responses from the array elements, and provides a high speed SDLC communication link to a host computer for use in data and command transfer.

SCOPE

This specification is a working document and will be used to communicate design goals and coordinate the design effort. As a working document, the specification will be revised as required during the design effort; however, it is and will remain consistent with commitments made to SMU/DARPA for the Portable Array Controller. Specification will be under control of the Project Engineer subject to the approval of the Program Manager. An "as built" final version of the document is required upon completion of the project.

This document contains requirements information at a level of detail which will insure that all of the functional requirements of the system are served. The specification describes all features of the system which will be delivered in the final product.

APPLICABLE SECTIONS

The following sections are directly referenced by, and are applicable to, this specification to the extent listed herein.

IAC - AETAC IAC	Array Element to Array Controller Interface Control
IAC - UIS	IAC User Interface Specification
IAC - ADCCP	IAC Host ADCCP Protocol Specification
IAC - HICD	IAC Host Interface Control

DESCRIPTION

The IAC is the central control element used in an array of data acquisition systems. The IAC acquires data from the array elements, accepts time tagging from the array elements, allows commands to be sent to the array elements, optionally records data on an Exabyte 8mm tape, and provides a data communication link through an SDLC formatted output to a host computer. This document covers specifications for the model IAC-100 which interfaces to PDAS-100s and RDAS-200s. The operator's interface to the Array Controller is provided by an integral keyboard and video monitor or by an optional serial interface.

REQUIREMENTS

OPERATIONAL

The IAC shall provide overall control of the array elements. The major functional requirements of the IAC are described below.

Data Acquisition

The IAC shall input data from the array elements, format these data into data messages, and transmit these data to the host computer. This shall be a continuous near real-time operation.

Time Tag and Synchronization

The IAC shall include a time reference receiver to acquire world-wide time. The IAC shall transmit time to the array elements to synchronize the array elements to minimize inter-element digitization skew and to enable array elements to time tag data accurately. The setting of the array element time shall be under the operators control.

Operator Control

The IAC shall be capable of accepting array element commands either locally through the IAC keyboard, from the host computer, and optionally through a serial interface. The array element command set shall include operations such as calibration, time read, time set, suspension of data from a channel, resumption of data from a channel, setting of sample rate for a channel, set of the preamplifier gain for a channel and acquisition of channel configuration information.

Data Recording

The IAC shall include the capability to archive data received from all array elements. This capability shall consist of storing data on a 8mm digital magnetic subsystem that can be optionally installed in the IAC.

PERFORMANCE

Number of Array Element Interfaces

The IAC-100 shall accommodate communication channels for up to 32 PDAS-100 or RDAS-200 array elements with a total of 96 channels of data with a maximum transfer rate of 19200 bits-per-second per array element. The IAC-100 shall accommodate any mix of standard array element data channel sample rates with a maximum aggregate sampling rate less than or equal to 360 samples-per-second for each array element.

Time Reference

The IAC shall be capable of receiving its time data from a synchronized clock. The IAC shall support the following Kinemetrics synchronized clocks that contain the parallel BCD option:

- OMEGA Model OM-DC
- GOES Model 468-DC
- DCF77 Model LF-DC

This time data will then be supplied to the array elements through the use of operator commands for time synchronization of all the elements of the array.

Synchronization

The IAC-100 shall provide channel to channel synchronization of 50 microseconds or less between any two array element channels in the array.

Host Interface Channel

The IAC shall provide a high speed communication channel for the host computer through SDLC formatted port(s). The minimum operational speed of the port shall be determined by the number of array elements in an array and by the rate at which they are collecting data. The IAC shall provide data and accept array element commands through this port.

<u>Electrical</u>

The Host Computer to the IAC electrical interface shall meet Electronic Industries Association RS-422 standard.

Transmit Clock	The transmit clock rate shall be supplied by the user and shall be at a rate which will support the aggregate data transfer rate of system. The minimum transmit clock rate shall be 1200 bits/second and the maximum transfer rate shall be 200 kbits/second.
Receive Clock	The receive clock rate shall be supplied by the user and shall be at a rate which will support the aggregate command transfer rate of system. The minimum receive clock rate shall be 1200

bits/second and the maximum transfer rate shall be 200 kbits/second.

Communication Protocol

The Host Computer to the IAC communication protocol shall be in compliance with the American National Standard X3.66-1979, for advance data communication control procedures (ADCCP). The subset of the ADCCP to be used for the communication protocol shall be defined in the IAC-ADCCP specification.

Format

The IAC shall communicate with the Host Computer thru a duplex communication link in a SDLC compatible format. The data field format shall be defined in the IAC-HICD specification.

Commands

Command messages for the IAC from the Host Computer shall be in SDLC-compatible format. The set of commands that the IAC shall accept from the Host Computer are found in the following sections.

CALCommand The CAL command shall be used to instruct a remote array element to run a calibration. Three calibration signal types; sine wave; pseudo-random noise; and pulse; shall be available for calibrating attached sensors. Calibration signals shall be activated for each individual sensor channel and shall be scheduled to start at any time. The number of repetitions, interval, duration, and amplitude shall be selectable with the CAL command.

REXMIT Command The REXMIT command shall be used by the host computer to retrieve an existing files from a remote array element.

REINIT Command The REINT command shall be used to reinitialize an array element.

TIMEREAD Command The TIMEREAD command shall be used by to obtain the current time from an array element's real time clock.

TIMESET Command The TIMESET command shall be used to set the current time in an array element's real time clock.

SUSPEND Command The SUSPEND command shall be used to instruct the selected array element to suspend data transmission.

RESUME Command The RESUME command shall be used to instruct the selected array element to resume data transmission.

RATESET Command	The RATESET command shall be used to change the sample rate of the selected array element channel.
GAINSET Command	The GAINSET command shall be used to change the preamplifier gain of the selected array element channel in a PDAS-100.
CONFIG Command	The CONFIG command shall be used to obtain configuration information from the selected array element.
HEALTH Command	The HEALTH command shall be used to obtain state of health information from the selected array element.

Local Keyboard Entry to IAC Protocol

Electrical

The interface shall be through a standard keyboard interface to the IAC.

Format

The user shall communicate with the IAC thru a local keyboard and user friendly windows via the monitor.

Commands

The set of commands that the IAC shall accept from user keyboard entry are the same as the commands in sections CAL thru HEALTH of this specification.

IAC to Array Element Interface

The IAC shall provide a high speed communication channel for the array element through a 19.2 kbps serial port.

Electrical

The IAC to array element electrical interface shall meet Electronic Industries Standard RS-232-C specification or optionally meet Electronic Industries Standard RS-422, and shall be transmitted at a rate of 19.2 kbps.

Communication Protocol

The IAC to array element protocol shall be in compliance with the protocol defined in the IAC-AETAC specification.

Format

The IAC shall pass commands generated by the Host Computer or the Local User Interface thru a duplex communication link using the format defined in the IAC-AETAC specification. The commands passed through this communication link are described in the following section.

Commands

The set of commands that the array elements shall accept from the IAC are the same as the commands in sections CAL thru RESUME of this specification.

IAC System Power

Operating Voltage

The IAC shall operate with single phase input voltage of 110 or 220 VAC. This operating voltage must be specified at the time the a system is ordered.

Line Frequency

The IAC shall be able to operate with a line frequency of 50Hz in a 220 VAC system or 60 Hz in a 110 VAC system.

Operating Power Requirements

The base system, which include a CPU card, a MACRO card, a RAMDISK card, a MULTIFUNCTION card, and a SDLC card, shall require a nominal 15 watts. The following is a list of options and their power requirements:

- The Kinemetrics synchronous clock shall require a nominal 25 watts.
- Each Digiboard array element smart communication board shall require a nominal 6 watts.
- A monochrome monitor shall require a nominal 30 watts.

Physical Characteristics

General

The IAC shall be packaged in a ruggedized weather resistant shock mounted rack enclosure. The enclosure shall contain easily removable covers and handles for portability. All power, data and communication (SDLC) ports shall be mounted on tne rear of the enclosure.

Weight

The nominal weight of the IAC shall be TBD pounds.

Size

The nominal size of the IAC shall be 25 inches wide by 51 inches high by 32 inches deep.

Array Element Cabling

The IAC shall accept 3 pairs of cable(s) from each array element array element for operation.

Environmental

Temperature

Operating	The IAC shall operate over the temperature range of 0 deg C to +55 deg C.
Storage	The storage temperature range of the IAC shall be 0 deg C to +55 deg C.

Humidity The operating and storage ranges for relative humidity shall be 5 to 95 percent at 40 deg C, non-condensing.

OPTIONS

EXABYTE TAPE CONTROLLER

The IAC shall support an Exabyte, Model EXB-8200, 8mm magnetic cartridge tape drive subsystem which will record data from all elements in the array. The Exabyte tape drive temperature specification is from +5 deg C to +40 deg. C.

HOST TO ARRAY CONTROLLER INTERFACE CONTROL DOCUMENT

(IAC - HICD)

GENERAL

INTRODUCTION

The communication link between the host computer and the array controller is through a SDLC formatted serial communication link operating at a speed between 1200 bits/second and 200 kbits/second. The transmit and receive transmission rates shall be controlled by a common or independent externally supplied clock source(s). Commands and data are transferred between the host computer and the array controller across this link. This document will detail the requirements for the ADCCP Address Field and the *Information* Field formats. The communication protocol is defined in IAC Host ADCCP Protocol Specification.

SCOPE

This specification is a working document and will be used to communicate design goals and coordinate the design effort. As a working document, the specification will be revised as required during the design effort; however, it is and will remain consistent with commitments made to SMU for the Array Controller. Specification will be under control of the Project Engineer subject to the approval of the Program Manager. An "as built" final version of the document is required upon completion of the project. The date at the top of the first page of any copy of the specification will be the revision date of that copy.

APPLICABLE SECTIONS

The following sections are directly referenced by, and are applicable to, this specification to the extent listed herein.

IAC	Inteleseis Array Controller Specification
IAC - ADCCP	IAC Host ADCCP Protocol Specification

DESCRIPTION

The Inteleseis Array Controller (IAC) is the central control element used in an array of data acquisition systems. The IAC acquires data from the array elements, accepts time tagging from the array elements, and allows commands to be sent to the array elements. This document covers the format of the ADCCP Address and Information fields.

ADDRESS FIELD FORMAT

The Address Field shall contain the selected address entered by an operator at the IAC.

INFORMATION FIELD STRUCTURE

Array Controller Transmitted Frames

The Information Field format for ADCCP frames transmitted by the Array Controller to the host computer shall of two types, a Response Type and a Data Type. Data Type Information fields contain at least 1000 bytes of channel header information and data. Individual data blocks contained within the data area of the Information field shall contain one second of sensor data. Response Type Information fields shall contain header information and as many bytes as required by the requested response. Each individual Information frame shall have the following structure:

TYPE,SN,CLK,CHAN,SMPL,TIME,SOH,RESV,DATA where:

TYPE - Type	(1 byte)
SN - Serial Number	(2 bytes)
CLK - Clock Status	(4 bits)
CHAN - Channel Number	(4 bits)
SAMP - Sample Rate Index	(1 byte)
TIME - Time Tag (seconds since 1970)	(4 bytes)
SOH - State of Health Data	(2 bytes)
RESV - Reserved area for status	(1 byte)
DATA - Data	(max 360 bytes)

The elements of each individual data block contained in the Information field are described in the following paragraphs. Note that the Information field shall contain as many of these individual one second data blocks as are needed to cause the Information field to be at least 1000 bytes in length, except response frames, which will be the length of an individual response frame.

Transfer Type (TYPE)

The data contained in TYPE field identifies what type of data is to be found in the DATA area of this channel data block. The following paragraphs describe all possible codes for this field.

Data Transfer Types

00H - Shall indicate that this is a data frame and the data field of this frame contains 16 bit data from an array channel

02H - Shall indicate that this is a data frame and the data field of this frame contains 24 bit data from an array channel.

04H - Shall indicate that this is an array element command frame and the data field of this frame contains the command string that has been sent to the selected array element.

0FH - Shall indicate that this is a unsolicted error frame and the data field of this frame contains an error message.

Response Transfer Types

20H - Shall indicate that the CAL command sent to this array element has been accepted.

21H - Shall indicate that the CAL command sent to this array element has been rejected.

24H - Shall indicate that the REINIT command sent to this array element has been accepted.

25H - Shall indicate that the REINIT command sent to this array element has been rejected.

26H - Shall indicate that the TIME READ command sent to this array element has been accepted and the data field of this frame contains the array element current time.

27H - Shall indicate that the TIME READ command sent to this array element has been rejected.

28H - Shall indicate that the TIME SET command sent to this array element has been accepted.

29H - Shall indicate that the TIME SET command sent to this array element has been rejected.

2AH - Shall indicate that the SUSPEND command sent to this array element has been accepted.

2BH - Shall indicate that the SUSPEND command sent to this array element has been rejected.

2CH - Shall indicate that the RESUME command sent to this array element has been accepted.

2DH - Shall indicate that the RESUME command sent to this array element has been rejected.

2EH - Shall indicate that the RATESET command sent to this array element has been accepted.

2FH - Shall indicate that the RATESET command sent to this array element has been rejected.

32H - Shall indicate that the CONFIG command sent to this array element has been accepted and the data field of this frame contains configuration data for this array element.

33H - Shall indicate that the CONFIG command sent to this array element has been rejected.

34H - Shall indicate that the HEALTH command sent to this array element has been accepted and the data field of this frame contains health data for this array element.

35H - Shall indicate that the HEALTH command sent to this array element has been rejected.

Serial Number (SN)

The SN field shall be an integer value stored in Intel format that shall contain the serial number of the array element that has sent this data and shall be in the range from 1 to 999

Clock Status (CLK)

The CLK field shall be a 4 bit entry that shall contain an value that indicates the status of the synchronous clock. A value of zero in this field shall indicate that the clock is in LOCK. A nonzero in this field shall indicate that the clock is not in LOCK.

Channel Number (CHAN)

The CHAN field shall be a 4 bit entry which shall contain the channel number for which the data contained in the data field has been collected and shall be in the range from 1 to 6.

Sample Rate Index (SAMP)

The SAMP entry shall be a 1 byte entry which shall contain the sample rate index entry for this channel. The following table contains all valid sample rate indexes for the PDAS-100 and the RDAS-200.

PDAS-100 Rates	Sample Rate Index
1000	0
500	1
200	2
100	3
50	4

20	5
10	6
5	7
2	8
1	9
5	10
2	11
1	12

RDAS-200 Rates	Sample Rate Index
200	13
120	14
100	15
80	16
60	17
50	18
40	19
20	20
10	21
5	22
2	23
1	24

Time Tag (seconds since 1970) (TIME)

The TIME entry shall be a long integer value stored in Intel format and shall contain the time represented as seconds since January 1, 1970 for which the first sample in this channel data block was collected.

State of Health (SOH)

The SOH entry shall be a integer value stored in Intel format and shall contain state of health information.

Reserved for Future (RESVF)

This entry shall be reserved for future use and will be set to 00H.

Data (DATA)

<u>Data Field for Raw Data</u>

The DATA field entry shall contain twice the sample rate number of bytes of raw data from the array element when in 16 bit format and 3 times the sample rate number of bytes of raw data from the array element when in 24 bit format. This data can contain calibration data along with other data. If the data is being collected in 16 or 24 bit format, then this field would contain the number of samples as specified in by the sample rate of the array element data.

<u>Data Field format (16 bit data)</u>

Data Field	Description
(2 * Sample Rate bytes)	16 bit data

Data Field format (24 bit data)

Data Field	Description
(3 * Sample Rate bytes)	24 bit data

Data Field for the CAL command

There shall be no data field transferred in response to the CAL command.

Data Field for the REINIT command

There shall be no data field transferred in response to the REINIT command.

Data Field for the TIMESET command

There shall be no data field transferred in response to the TIMESET command.

Data Field for the TIMEREAD command

The data field transmitted by the array element in response to the TIMEREAD command shall be 34 bytes in length. This includes slashes, commas, and colons. The format of the field shall be as follows:

Data Field format:

Data Field:	Description:	
ARRAY ELEMENT TIME	MO/DA/YR,HH:MM:SS	
	MO is month	01 thru 12
	DA is day	01 thru 31

YR is year	00 thru 99
HH is hour	00 thru 23
MM is minute	00 thru 59
SS is second	00 thru 59

SYNCHRONOUS CLOCK TIME MO/DA/YR,HH:MM:SS

MO is month	01 thru 12
DA is day	01 thru 31
YR is year	00 thru 99
HH is hour	00 thru 23
MM is minute	00 thru 59
SS is second	00 thru 59

Data Field for the SUSPEND command

The data field transmitted by the array element in response to the SUSPEND command shall be 1 byte in length.

Data Field format

Data Field:	Description:
channel number	1 thru 6

Data Field for the RESUME command

The data field transmitted by the array element in response to the RESUME command shall be 1 byte in length.

Data Field format

Data Field:	Description:
channel number	1 thru 6

Data Field for the RATESET command

The data field transmitted by the array element in response to the RATESET command shall be 1 byte in length.

Data Field format

Data Field:	Description:
channel number	1 thru 6

Data Field for the CONFIG command

The data field transmitted by the array element in response to the CONFIG command shall be 360 bytes in length.

Data Field format

Data Field:	Description:
(60 bytes)	general array element info
(50 bytes)	channel 1 info
(50 bytes)	channel 2 info
(50 bytes)	channel 3 info
(50 bytes)	channel 4 info
(50 bytes)	channel 5 info
(50 bytes)	channel 6 info

General array element information format

Data Field:	Size:
Clock drift rate microsec/day	4 bytes
Clock Type	2 bytes
Jam Set Limit	2 bytes
Minimum Correction	2 bytes
Update period in seconds	2 bytes
Serial Number	2 bytes
Number of Degrees Latitude	2 bytes
Number of Minutes Latitude	2 bytes
Number of Seconds Latitude	2 bytes
Number of Hundredths Latitude	2 bytes
Number of Degrees Longitude	2 bytes
Number of Minutes Longitude	2 bytes
Number of Seconds Longitude	2 bytes
Number of Hundredths Longitude	2 bytes
Latitude Direction	1 byte
Longitude Direction	1 byte
Elevation	20 bytes
Comment	8 bytes
	60 bytes

Channel information format

Data Field	Size
Channel Sample Rate Index	2 bytes
Channel Preamp Gain	2 byte

Channel enabled ? (Y/N)	1 byte
Channel Name	8 byte
Low Cut filter ? (Y/N)	1 byte
Sensor Sensitivity	10 bytes
Comment	20 bytes
Reserved for future use	6 bytes
	50 bytes

Data Field for the HEALTH command

The data field transmitted by the array element in response to the HEALTH command shall be 360 bytes in length.

Data Field format

Data Field	Description
(60 bytes)	general array element info
(50 bytes)	channel 1 info
(50 bytes)	channel 2 info
(50 bytes)	channel 3 info
(50 bytes)	channel 4 info
(50 bytes)	channel 5 info
(50 bytes)	channel 6 info

HOST COMPUTER Transmitted Frames

The Information Field format for ADCCP frames transmitted by the host computer to the Array Controller shall have the following structure:

CMD, SN, PARM where:

CMD -	Command string	(8 bytes)
SN -	Serial Number	(3 bytes)
PARM -	Parameters string	(max 120 bytes)

The elements of the frame are described in the following paragraphs.

Command Field (CMD)

The command strings received by the array element are left justified, upper case ASCII text strings, that are spaced filled to the right for commands less than 8 characters in length.

CAL command

The command string for CAL shall be "CAL"

REINIT command

The command string for REINIT shall be "REINIT".

TIMEREAD command

The command string for TIMEREAD shall be "TIMEREAD".

TIMESET command

The command string for TIMESET shall be "TIMESET".

SUSPEND command

The command string for SUSPEND shall be "SUSPEND".

RESUME command

The command string for RESUME shall be "RESUME".

RATESET command

The command string for RATESET shall be "RATESET".

CONFIG command

The command string for CONFIG shall be "CONFIG".

HEALTH command

The command string for HEALTH shall be "HEALTH".

Serial Number (SN)

The serial number string received by the array element shall be right justified, ASCII text string, that is zero filled to the right for serial numbers less than 3 digits in length.The SN field contains the serial number shall be in the range from 1 to 999 for the selected array element.

Parameters Fields (PARMS)

CAL (Calibration) command

The CAL command shall causes the array element to run a calibration test. The data sections in the CAL command are separated by a comma [,]. The data shall be transmitted to the array element in ASCII format and shall be terminated with a 0DH (carriage return).

Command string format

Command string:	Description:
channel number [,]	1 thru 6
calibration type [,]	S, N, or P
start time [,]	MO/DA/YR,HH:MM:SS
	MO is month 01 thru 12
	DA is day 01 thru 31
	YR is year 00 thru 99
	HH is hour 00 thru 23
	MM is minute 00 thru 59
	SS is second 00 thru 59
duration [,]	HHH:MM:SS
	HHH is hour 000 thru 999
	MM is minute 00 thru 59
	SS is second 00 thru 59
number or reps [,]	RRRR
	RRRR is 0000 thru 9999
interval [,]	HHH:MM:SS
	HHH is hour 000 thru 999
	MM is minute 00 thru 5
	SS is second 00 thru 59
freq [,]	FFF.fff
	FFF.fff is 000.001 thru 500.000 Hz
	or
bandwidth [,]	BBB.bbb
	BBB.bbb is 000.001 thru 500.000 Hz

pulse width[,]	PPP
	PPP is 001 thru 100
amplitude	AAAA
	AAAA is 0000 thru 4500
0DH	Termination code

REINIT (initialize) command

The REINIT command shall cause the array element to perform a cold start initialization causing the array element to return to it default startup condition. No command string shall be received for the REINIT command.

TIMEREAD command

The TIMEREAD command shall causes the array element to read its time and transmit it to the array controller, which will then append the time read from the synchronous clock to the data and pass it on to the host computer. No command string shall be received for the TIMEREAD command.

TIMESET command

The TIMESET command shall causes the array element to set its time to the time received from the host or from the array controller's synchronous clock if the data field is set to all zero's. The data sections in the TIMESET command are separated by a comma [,]. The data shall be transmitted to the array element in ASCII format and shall be terminated with a 0DH (carriage return). The format of the TIMESET command to the array element shall be as follows:

Command string format

Command string:	Description:
time	MO/DA/YR,HH:MM:SS
	MO is month 01 thru 12
	DA is day 01 thru 31
	YR is year 00 thru 99
	HH is hour 00 thru 23
	MM is minute 00 thru 59
	SS is second 00 thru 59
0DH	Termination code

SUSPEND command

The SUSPEND command shall cause the array element to suspend its data collection. The channel number shall be received as an ASCII character and shall be terminated with a 0DH.

Command string format

Command string:	Description:
channel number	1 thru 6
0DH	Termination code

RESUME command

The RESUME command shall causes the array element to resume its data collection. The channel number shall be received as an ASCII character and terminated with a 0DH.

Command string format

Command string	Description
channel number	1 thru 6
0DH	Termination code

RATESET command

The data sections in the RATESET command are separated by a comma [,]. The data shall be transmitted to the array element in ASCII format and shall be terminated with a 0DH (carriage return).

Command string format

Command string	Description
channel number	1 thru 6
rate	RRRR.r RRRR.r for RDAS-200 rates 0001.0, 0002.0, 0005.0, 0010.0, 0020.0, 0040.0, 0050.0 ,0060.0, 0080.0, 0100.0, 0120.0 s/s RRRR.r for PDAS-100 rates 0000.1, 0000.2, 0000.5, 0001.0, 0002.0, 0005.0, 0010.0, 0020.0, 0050.0, 0100.0, 0200.0, 0500.0, 1000.0
0DH	Termination code

CONFIG command

The CONFIG command shall cause the array element to transfer configuration information data to the host computer for channels 1 thru 6. No command string shall be received for the CONFIG command.

HEALTH command

The HEALTH command shall cause the array element to transmit system status for each channel connected to the array element to the host computer. No command string shall be received for the HEALTH command.

ARRAY ELEMENT TO ARRAY CONTROLLER INTERFACE CONTROL DOCUMENT (IAC - AETAC ICD)

GENERAL

INTRODUCTION

The communication link between the array elements and the array controller is through a serial communication link operating at a speed of 19.2 kbps. Commands and data are transferred between the array controller and the array element across this link. This document will detail the requirements for the data frame format and the communication protocol.

SCOPE

This specification is a working document and will be used to communicate design goals and coordinate the design effort. As a working document, the specification will be revised as required during the design effort; however, it is and will remain consistent with commitments made to SMU for the Array Controller. Specification will be under control of the Project Engineer subject to the approval of the Program Manager. An "as built" final version of the document is required upon completion of the project.

DESCRIPTION

The IAC is the central control element used in an array of data acquisition systems. The IAC acquires data from the array elements, accepts time tagging from the array elements, allows commands to be sent to the array elements. This document covers the interface specifications for communications between the IAC and the array elements.

FRAME STRUCTURE

ARRAY ELEMENT TRANSMITTED FRAMES

All transmissions are in frames and each frame conforms to the following structure:

SYNC,TYPE,SN,CHAN,CALS,DATE,TIME,RESV,DATA,FCS,EOFwhere:

SYNC	- Sync character (E3H)	(1 byte)
TYPE	- Type	(1 byte)
SN	- Serial Number	(3 bytes)
CHAN	- Channel Number	(1 byte)
CALS	- Calibration Sample Number	(1 byte)
DATE	- Date Tag (seconds since 1970)	(4 bytes)
TIME	- Time Tag (milliseconds)	(2 bytes)
STAT	- Sample Rate Index	(1 byte)
RESV	- Reserved area for status	(10 bytes)
DATA	- Data	(max 1000 bytes)
FCS	- Frame Check Sequence	(2 bytes)
EOF	- End of Frame (E5H)	(1 byte)
		----------
		*1028 bytes

* If data field contains any special characters that require escape sequences this number can be larger. If the data field required is smaller than the total may be less than this. All entries are in Intel format. The elements of the frame are described in the following paragraphs.

Frame Synchronization Character (SYNC)

All frames start with a synchronization character. The synchronization character is E3H. In order to provide transparency, the synchronization character is prohibited from occurring in any other field of a frame. If the synchronization character is found in a buffer to be transmitted, it must be replaced with the two byte sequence, E0H followed by E3H.

Transfer Type (TYPE)

The data contained in TYPE field identifies what type of data is to be found in the DATA area of this frame. The following paragraphs describe all possible codes for this field.

Data Transfer Types

00H - Indicates that this is a data frame and the data field of this frame contains 16 bit data from an array channel.

01H - Indicates that this is a data frame and the data field of this frame contains retransmitted 16 bit data from an array channel.

02H - Indicates that this is a data frame and the data field of this frame contains 24 bit data from an array channel.

03H - Indicates that this is a data frame and the data field of this frame contains retransmitted 24 bit data from an array channel.

04H - Indicates that this is a data frame and the data field of this frame contains 16 bit data from an array channel. The first sample of calibration data is contained in this buffer. The sample number of the first calibration data is found in the CALS field of this frame.

05H - Indicates that this is a data frame and the data field of this frame contains retransmitted 16 bit data from an array channel. The first sample of calibration data is contained in this buffer. The sample number of the first calibration data is found in the CALS field of this frame.

06H - Indicates that this is a data frame and the data field of this frame contains 24 bit data from an array channel. The first sample of calibration data is contained in this buffer. The sample number of the first calibration data is found in the CALS field of this frame.

07H - Indicates that this is a data frame and the data field of this frame contains retransmitted 24 bit data from an array channel. The first sample of calibration data is contained in this buffer. The sample number of the first calibration data is found in the CALS field of this frame.

08H - Indicates that this is a data frame and the data field of this frame contains 16 bit data from an array channel. The last sample of calibration data is contained in this buffer. The sample number of the last calibration data is found in the CALS field of this frame.

09H - Indicates that this is a data frame and the data field of this frame contains retransmitted 16 bit data from an array channel. The last sample of calibration data is contained in this buffer. The sample number of the last calibration data is found in the CALS field of this frame.

0AH - Indicates that this is a data frame and the data field of this frame contains 24 bit data from an array channel. The last sample of calibration data is contained in this buffer. The sample number of the last calibration data is found in the CALS field of this fram

0BH - Indicates that this is a data frame and the data field of this frame contains retransmitted 24 bit data from an array channel. The last sample of calibration data is contained in this buffer. The sample number of the last calibration data is found in the CALS field of this frame.

0FH - Indicates that this is a usolicted error frame and the data field of this frame contains an error message.

Response Transfer Types

20H - Indicates that the CAL command sent to this array element has been accepted.

21H - Indicates that the CAL command sent to this array element has been rejected.

22H - Indicates that the REXMIT command sent to this array element has been accepted.

23H - Indicates that the REXMIT command sent to this array element has been rejected.

24H - Indicates that the REINIT command sent to this array element has been accepted.

25H - Indicates that the REINIT command sent to this array element has been rejected.

26H - Indicates that the TIME READ command sent to this array element has been accepted and the data field of this frame contains the array element current time.

27H - Indicates that the TIME READ command sent to this array element has been rejected.

28H - Indicates that the TIME SET command sent to this array element has been accepted.

29H - Indicates that the TIME SET command sent to this array element has been rejected.

2AH - Indicates that the SUSPEND command sent to this array element has been accepted.

2BH - Indicates that the SUSPEND command sent to this array element has been rejected.

2CH - Indicates that the RESUME command sent to this array element has been accepted.

2DH - Indicates that the RESUME command sent to this array element has been rejected.

2EH - Indicates that the RATESET command sent to this array element has been accepted.

2FH - Indicates that the RATESET command sent to this array element has been rejected.

30H - Indicates that the GAINSET command sent to this array element has been accepted.

31H - Indicates that the GAINSET command sent to this array element has been rejected.

32H - Indicates that the CONFIG command sent to this array element has been accepted and the data field of this frame contains configuration data for this array element.

33H - Indicates that the CONFIG command sent to this array element has been rejected.

34H - Indicates that the HEALTH command sent to this array element has been accepted and the data field of this frame contains health data for this array element.

35H - Indicates that the HEALTH command sent to this array element has been rejected.

Serial Number (SN)

The SN field contains the serial number in the range from 1 to 999 for the array element that is sending data.

Channel Number (CHAN)

The CHAN field contains the channel number for which the data contained in the data field has been collected in the range from 1 to 6.

Calibration Sample Number (CALS)

When the TYPE field contains a 04H, 05H, 06H, or 07H this field will contain the sample number of the data where a calibration cycle was started. When the TYPE field contains a 08H, 09H, 0AH or 0BH this field will contain the sample number of the data where a calibration cycle was completed.

Date Time Tag (seconds since 1970) (DATE)

The DATE field contains the date represented as seconds since January 1, 1970.

Time Tag (milliseconds) (TIME)

The TIME field contains the time in milliseconds since the last second.

Data (DATA)

Data Field for Raw Data

The DATA field contains 1000 bytes of raw data from the array element when in 16 bit format and 750 bytes of raw data from the array element when in 24 bit format. This data can contain calibration data along with other data. If the data are being collected in 16 bit format, then this field would contain 500 samples of the array element data. If t\ being collected in 24 bit format then this field would contain 250 samples of the array element data.

Data Field format (16 bit data) Data Field Description ---------
- ----------- (1000 bytes) 16 bit data

Data Field format (24 bit data) Data Field Description ---------
- ----------- (750 bytes) 24 bit data

Data Field for the CAL command

There is no data field transferred in response to the CAL command.

Data Field for the REXMIT command

The DATA field contains 1000 bytes of raw data from the array element when in 16 bit format and 750 bytes of raw data from the array element when in 24 bit format. These data can contain calibration data along with other data. If the data are being collected in 16 bit format then this field would contain 500 samples of the array element data. If the data are being collected in 24-bit format then this field would contain 2 ..amples of the array element data. The format of the data field is as follows:

Data Field format (16 bit data) Data Field Description ----------
----------- (1000 bytes) 16 bit data

Data Field format (24 bit data) Data Field Description ---------
- ----------- (750 bytes) 24 bit data

Data Field for the REINIT command

There is no data field transferred in response to the REINIT command.

Data Field for the TIMESET command

There is no data field transferred in response to the TIMESET command.

Data Field for the TIMEREAD command

The data field transmitted by the array element in response to the TIMEREAD command is 17 bytes in length. This includes slashes, commas, and colons. The format of the field is as follows:

Data Field format Data Field Description ----------

----------- TIME

MO/DA/YR,HH:MM:SS

MO is month 01 thru 12

DA is day 01 thru 31

YR is year 00 thru 99

HH is hour 00 thru 23

MM is minute 00 thru 59

SS is second 00 thru 59

Data Field for the SUSPEND command

The data field transmitted by the array element in response to the SUSPEND command is 1 byte in length.

Data Field format Data Field Description ----------

----------- channel number 1 thru 6

Data Field for the RESUME command

The data field transmitted by the array element in response to the RESUME command is 1 byte in length.

Data Field format	Data Field	Description ----------
-----------	channel number	1 thru 6

Data Field for the RATESET command

The data field transmitted by the array element in response to the RATESET command is 1 byte in length.

Data Field format	Data Field	Description ----------
-----------	channel number	1 thru 6

Data Field for the GAINSET command

The data field transmitted by the array element in response to the GAINSET command is 1 byte in length.

Data Field format	Data Field	Description ----------
-----------	channel number	1 thru 6

Data Field for the CONFIG command

The data field transmitted by the array element in response to the CONFIG command is 1000 bytes in length.

Data Field format Data Field

Description

general array element info	(150 bytes)
channel 1 info	(150 bytes)
channel 2 info	(150 bytes)
channel 3 info	(150 bytes)
channel 4 info	(150 bytes)
channel 5 info	(150 bytes)
channel 6 info	(150 bytes)

General array element information format Data Field Size

TypeClock drift rate microsec/day	4 bytes
longClock Type	2 bytes
intJam Set Limit	2 bytes
intMinumum Correction	2 bytes
intUpdate period in seconds	2 bytes
intSerial Number	2 bytes
intNumber of Degrees Latitude	2 bytes
intNumber of Minutes Latitude	2 bytes
intNumber of Seconds Latitude	2 bytes
intNumber of Hundredths Latitude	2 bytes
intNumber of Degrees Longitude	2 bytes
intNumber of Minutes Longitutde	2 bytes
intNumber of Seconds Longitude	2 bytes
intNumber of Hundredths Longitude	2 bytes
intLatitude Direction	1 byte
asciiLongitude Direction	1 byte

asciiElevation	20 bytes
asciiComment	48 bytes
ascii	--------
	100 bytes

Channel information format Data Field	Size
TypeChannel Sample Rate Index	2 bytes
intChannel Preamp Gain	2 byte
intChannel enabled ? (Y/N)	1 bytes
asciiChannel Name	8 byte
asciiLow Cut filter ? (Y/N)	1 byte
asciiSensor Sensitivity	10 bytes
asciiComment	20 bytes
asciiReserved for future use	106 bytes
	---------
	150 bytes

Data Field for the HEALTH command

The data field transmitted by the array element in response to the HEALTH command is 1000 bytes in length.

Data Field format Data Field Description --------------------	
general array element info	(100 bytes)
channel 1 info	(150 bytes)
channel 2 info	(150 bytes)
channel 3 info	(150 bytes)

channel 4 info	(150 bytes)
channel 5 info	(150 bytes)
hannel 6 info	(150 bytes)

Frame Check Sequence (FCS)

All frames include a 16-bit frame check sequence (FCS) just prior to the end of frame character for error detection purposes. The FCS field contains a 16 bit CRC for the frame being sent.

End of Frame (EOF)

All frames end with an end of frame character. The end of frame character is E5H. In order to provide transparency the synchronization character is prohibited from occurring any other field of a frame. If the synchronization character is found in a buffer to be transmitted it must be replaced with the two byte sequence, E0H followed by 45H.

ARRAY ELEMENT RECEIVED FRAMES

All transmissions are in frames and each frame conforms to the following structure:

SYNC,COMMAND,PARAMETERS,FCS,EOFwhere:

SYNC	- Sync character (E3H)	(1 byte)
CMD	- Command string	(8 bytes)
SN	- Serial Number	(3 bytes)
PARM	- Parameters string	(max 120 bytes)
FCS	- Frame Check Sequence	(2 bytes)
EOF	- End of Frame (E5H)	(1 byte)

The elements of the frame are described in the following paragraphs.

Frame Synchronization Character (SYNC)

All frames start with a synchronization character. The synchronization character is E3H. In order to provide transparency the synchronization character is prohibited from occurring in any other field of a frame. If the synchronization character is found in a buffer to be transmitted it must be replaced with the two byte sequence, E0H followed by 43H.

Command Field (CMD)

The commands strings received by the array element are left justified, upper case ASCII text strings, that are spaced filled to the right for commands less than 8 characters in length.

CAL command

The command string for the CAL command is "CAL".

REXMIT command

The command string for the REXMIT command is "REXMIT".

REINIT command

The command string for the REINIT command is "REINIT".

TIMEREAD command

The command string for the TIMEREAD command is "TIMEREAD".

TIMESET command

The command string for the TIMESET command is "TIMESET".

SUSPEND command

The command string for the SUSPEND command is "SUSPEND".

RESUME command

The command string for the RESUME command is "RESUME".

RATESET command

The command string for the RATESET command is "RATESET".

GAINSET command

The command string for the GAINSET command is "GAINSET".

CONFIG command

The command string for the CONFIG command is "CONFIG".

HEALTH command

The command string for the HEALTH command is "HEALTH".

Serial Number (SN)

The SN field contains the serial number in the range from 1 to 999 for the array element that is sending data.

Parameters Fields (PARMS)

CAL (Calibration) command

The CAL command shall causes the array element to run a calibration test. The data sections in the CAL command are seperated by a comma [,]. The data is transmitted to the array element in ASCII format and is terminated with a 0DH (carriage return).

Command string format

Command string

Description------------------------channel number [,]

1 thru 6 calibration type [,]

S, N, or P start time [,]

MO/DA/YR,HH:MM:SS

MO is month 01 thru 12

DA is day 01 thru 31

YR is year 00 thru 99

HH is hour 00 thru 23

MM is minute 00 thru 59

SS is second 00 thru 59duration [,]

HHH:MM:SS

HHH is hour 000 thru 999

MM is minute 00 thru 59

SS is second 00 thru 59number or reps [,]

RRRR

RRRR is 0000 thru 9999interval [,]

HHH:MM:SS

HHH is hour 000 thru 999

MM is minute 00 thru 59

SS is second 00 thru 59freq [,]

FFF.fff

FFF.fff is

000.001 thru 500.000 Hzorbandwidth [,]

BBB.bbb

BBB.bbb is

000.001 thru 500.000 Hzorpulse width[,]

PPP

PPP is 001 thru 100amplitude

AAAA

AAAA is 0000 thru 45000DH

Termination code

REXMIT (retransmit) command

The REXMIT command shall causes the array element to transmit all existing files to the array controller. The REXMIT command is only valid when the array element is suspended. No command string shall be received for the REXMIT command.

REINIT (initialize) command

The REINIT command shall cause the array element to perform a cold start initialization. No command string shall be received for the REINIT command.

TIMEREAD command

The TIMEREAD command shall causes the array element to read its time and transmit it to the array controller. No command string shall be received for the TIMEREAD command.

TIMESET command

The TIMESET command shall causes the array element to set its time to the time received from the array controller. The data sections in the TIMESET command are seperated by a comma [,]. The data is transmitted to the array element in ASCII format and is terminated with a 0DH (carriage return). The format of the TIMESET command to the array element is as follows:

Command string format

Command string

Description--------------------time

MO/DA/YR,HH:MM:SS

MO is month 01 thru 12

DA is day 01 thru 31

YR is year 00 thru 99

HH is hour 00 thru 23

MM is minute 00 thru 59

SS is second 00 thru 590DH

- Termination code

SUSPEND command

The SUSPEND command shall causes the array element to suspend its data collection. The channel number is received as an ASCII character and is terminated with a 0DH.

Command string format

Command string

Description--------------------channel number 1 thru 6

0DH

Termination code

RESUME command

The RESUME command shall causes the array element to resume its data collection. The channel number is received as an ASCII character and terminated with a 0DH.

Command string format

Command string

Description----------------------channel number 1 thru 6

0DH

Termination code

RATESET command

The data sections in the RATESET command are seperated by a comma [,]. The data is transmitted to the array element in ASCII foramt and is terminated with a 0DH (carriage return).

Command string format

Command string

Description----------------channel number 1 thru 6

rate

RRRR.r

RRRR.r for RDAS-200 rates

0001.0, 0002.0, 0005.0,

0010.0, 0020.0, 0040.0,

0050.0 ,0060.0, 0080.0,

0100.0, 0120.0 s/s

RRRR.r for PDAS-100 rates

0000.1, 0000.2, 0000.5,

0001.0, 0002.0, 0005.0,

0010.0, 0020.0, 0050.0,

0100.0, 0200.0, 0500.0,

1000.00DH

Termination code

GAINSET command

The data sections in the GAINSET command are seperated by a comma [,]. The data is transmitted to the array element in ASCII format and is terminated with a 0DH (carriage return).

Command string format

Command string

Description-------------channel number 1 thru 6

GGG for RDAS-200 gains

001

GGG for PDAS-100 gains

001, 010, 1000DH

Termination code

<u>CONFIG command</u>

The CONFIG command shall causes the array element to transfer configuration information data ro the array controller for channels 1 thru 6. No command string shall be received for the CONFIG command.

<u>HEALTH command</u>

The HEALTH command shall causes the array element to transmit system status for each channel connected to the array element. No command string shall be received for the HEALTH command.

Frame Check Sequence (FCS)

All frames include a 16-bit frame check sequence (FCS) just prior to the end of frame character for error detection purposes. The FCS field contains a 16 bit CRC for the frame being sent.

End of Frame (EOF)

All frames end with a end of frame character. The end of frame character is E5H. In order to provide transparency the synchronization character is prohibited from occurring any other field of a frame. If the synchronization character is found in a buffer to be transmitted it must be replaced with the two byte sequence, E0H followed by 45H.

Acknowledge (ACK) Frame

All transmissions that are accepted by the receiving side of the link must acknowledge the transmitter with an ACKNOWLEDGE frame. The following defines the ACKNOWLEDGE frame.

SYNC,ACK,EOFwhere:

SYNC	- Sync character (E3H)	(1 byte)
ACK	- Acknowledge Character(E1H)	(1 byte)
EOF	- End of Frame (E5H)	(1 byte)

No Acknowledge (NAK) Frame

All transmissions that are rejected by the receiving side of the link must send a no acknowledge the transmitter with an NO ACKNOWLEDGE frame. The following defines the NO ACKNOWLEDGE frame.

SYNC,NAK,EOFwhere:

SYNC	- Sync character (E3H)	(1 byte)
NAK	- No Acknowledge Character(E2H)	(1 byte)
EOF	- End of Frame (E5H)	(1 byte)

Cancel (CAN) Frame

All transmissions that are rejected by the receiving side of the link 10 times must send a cancel message to the transmitter with an CANCEL frame. The following defines the CANCEL frame. SYNC,CAN,EOFwhere:

SYNC	- Sync character (E3H)	(1 byte)

CAN	- Cancel Character(E4H)	(1 byte)
EOF	- End of Frame (E5H)	(1 byte)

SPECIAL COMMUNICATION CHARACTER SET

The following are defined as characters that are reserved for communication protocol and will not appear in the frame except where specified. E0H - FLAG which indicates the next character was in the range of the special communication character set and the next character received has to be XOR with A0H to be returned to its original value. The E0H must be thrown away by the receiver. E1H - ACK which indicates that the last block was accepted by the receiver. E2H - NAK which indicates that the last block was rejected by the receiver and should be retransmitted by the transmitter. E3H - SYNC which is the synchronization flag for the receiver to trigger off of to start receiving a block. E4H - CAN which indicates that the last block was retried 10 times and failed 10 times. E5H - EOF which is the flag to indicate that a complete block has been transferred.

ARRAY ELEMENT AND ARRAY CONTROLLER TRANSMITTER

The transmitters on both sides of the communication link are responsible for assembling the frames in the proper sequence as defined previously in this document. When a special communication character falls in a field where these characters are not permitted the transmitter must replace that character with a two character sequence as follows:

E0H followed by the character in question XOR with A0H.

All possible combinations are as follows:

If character = E0H then replace with E0H,40H

If character = E1H then replace with E0H,41H

If character = E2H then replace with E0H,42H

If character = E3H then replace with E0H,43H

If character = E4H then replace with E0H,44H

If character = E5H then replace with E0H,45H

After transmitting a block the transmitter end of the link must wait for either an ACK, NACK, or CAN frame from the receiver on the end of the link. If a NACK frame is received then the block must be sent again. If an ACK frame is received then the next block can be sent. If a CAN frame is received then the next block should be sent and an error logged.

ARRAY ELEMENT AND ARRAY CONTROLLER RECEIVER

The receivers on both ends of the communication link are responsible for disassembling the frames in the proper sequence as defined previously in this document. After receiving a block of data from the transmitter, the receiver must run a CRC-16 check on the data to determine if any errors occurred during transmission. If an error did occur, then a NAK frame must be sent to the other end of the link and the block discarded. If this is the 10th time this block is received with errors then a CAN frame should be sent to the other end of the link.. If the block is received with no errors then an ACK frame must be sent to the end of the link so that the next block may be sent. When a special communication character falls in a field where these characters are not permitted the receiver must replace the two byte sequence with the original character before passing it on to the rest of the system.All *possible combinations of two byte sequence* and their one byte replacements are as follows:

If sequence	=	E0H,40H then replace with	E0H
If sequence	=	E0H,41H then replace with	E1H
If sequence	=	E0H,42H then replace with	E2H
If sequence	=	E0H,43H then replace with	E3H
If sequence	=	E0H,44H then replace with	E4H
If sequence	=	E0H,45H then replace with	E5H

All of the functional requirement documents have been developed as working documents between SMU/DARPA and the two major suppliers, Teledyne Geotech and Science Horizons Inc. The requirements presented in this report were generated by Teledyne Geotech with input from Science Horizons on data interface issues and communication protocols. The requirements are subject to change as is deemed neccesary for the development of the system that will best support the requirements of the GSETT2 experiments and distributed NDC concept.

In Chapter three we discuss the normal operations of the Lajitas seismic station and SMU distributed NDC, along with some research and development activities at the NDC. Some interesting seismic events recorded at the NDC during this reporting period have been analyzed utilizing GSETT2 type software tools as a means to prepare for the experiments, which are curently scheduled to begin in early 1990.

CHAPTER THREE

NORMAL OPERATIONS OF THE LAJITAS, TX SEISMIC STATION

GENERAL

The Lajitas seismic station has been continuously transmitting data to the SMU distributed National Data Center since July 1, 1988. At SMU, seismic data is routinely archived on disk in CSS version 2.8 database format. The data is kept on line for two weeks and is then permanently archived on magnetic tape. In preparation for participation in the GSETT2, global-data-exchange experiment, several different data analysis packages are being tested. Routine GSETT2 analysis will not be performed on a daily basis until the experiment begins, currently scheduled for early 1990. Interesting seismic events are analyzed with various software, including AH, SAC, IPX2, and SUNPICK. A newer release of IPX2 is being developed and will be evaluated upon its delivery to SMU. Most of the data displays in this report were generated using SUNPICK, except for the spectra displays, which were generated by IPX2. Software developed at SMU provides a way to plot the data automatically, on a laser printer, once every four hours for short period channels, and every twelve hours for broad band channels. The hard copy displays have been valuable for quality control purposes during the evaluation of the data acquisition software. Several problems have been discovered and diagnosed using this software. Figure 3.1 shows a four hour display of the short period vertical channel. In Figures 3.2 and 3.3 we show the two horizontal short period channels for the same time period. The seismic event shown is a magnitude 5.2 earthquake centered off the west coast of central Mexico at a distance of approximately 800 kilometers from Lajitas. The short period data is decimated by a factor of 7 to 1 prior to plotting, which

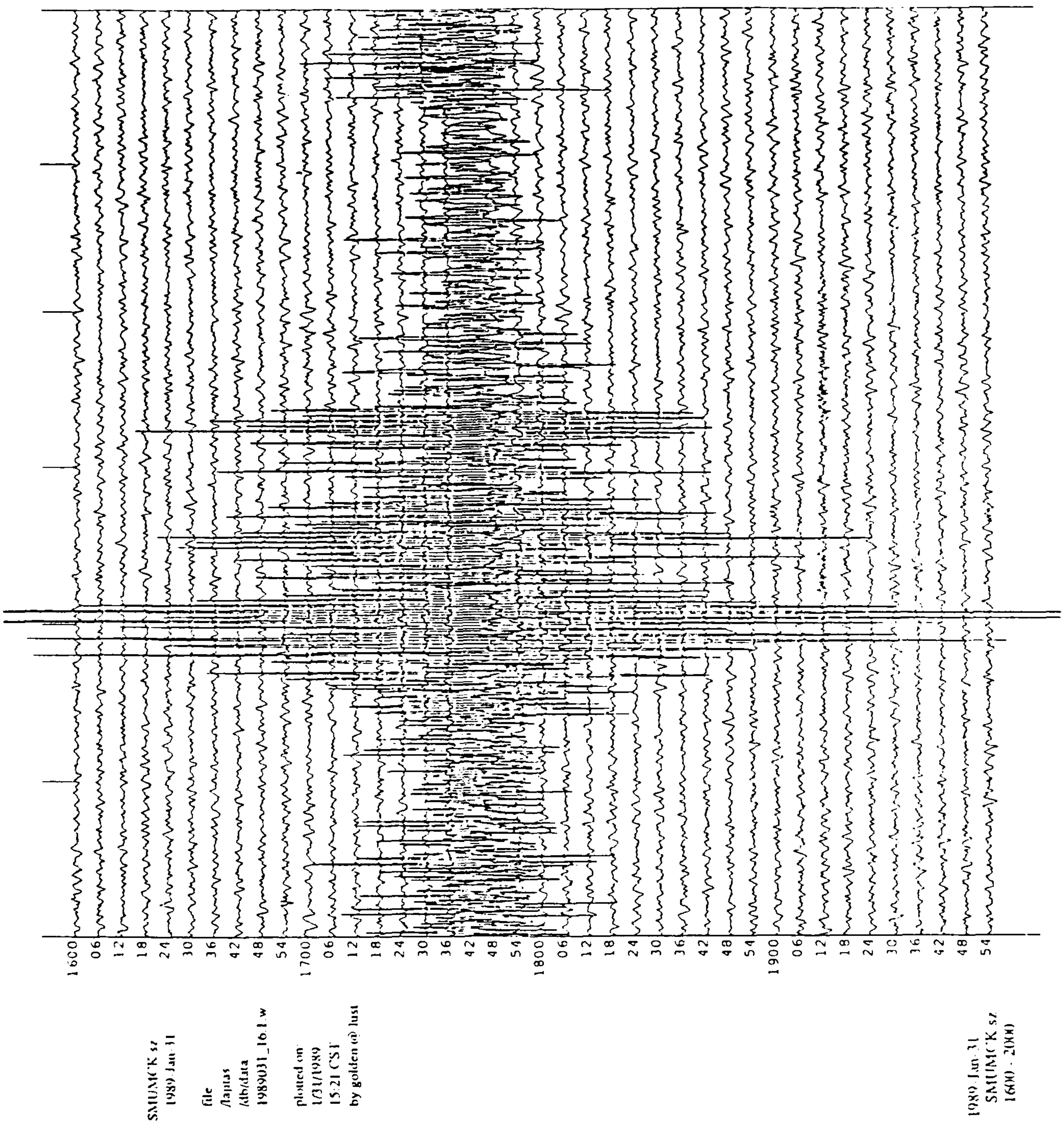

Figure 3.1. Four hour display of vertical short period data channel, including ambient noise and a regional earthquake, recorded at Lajitas, TX.

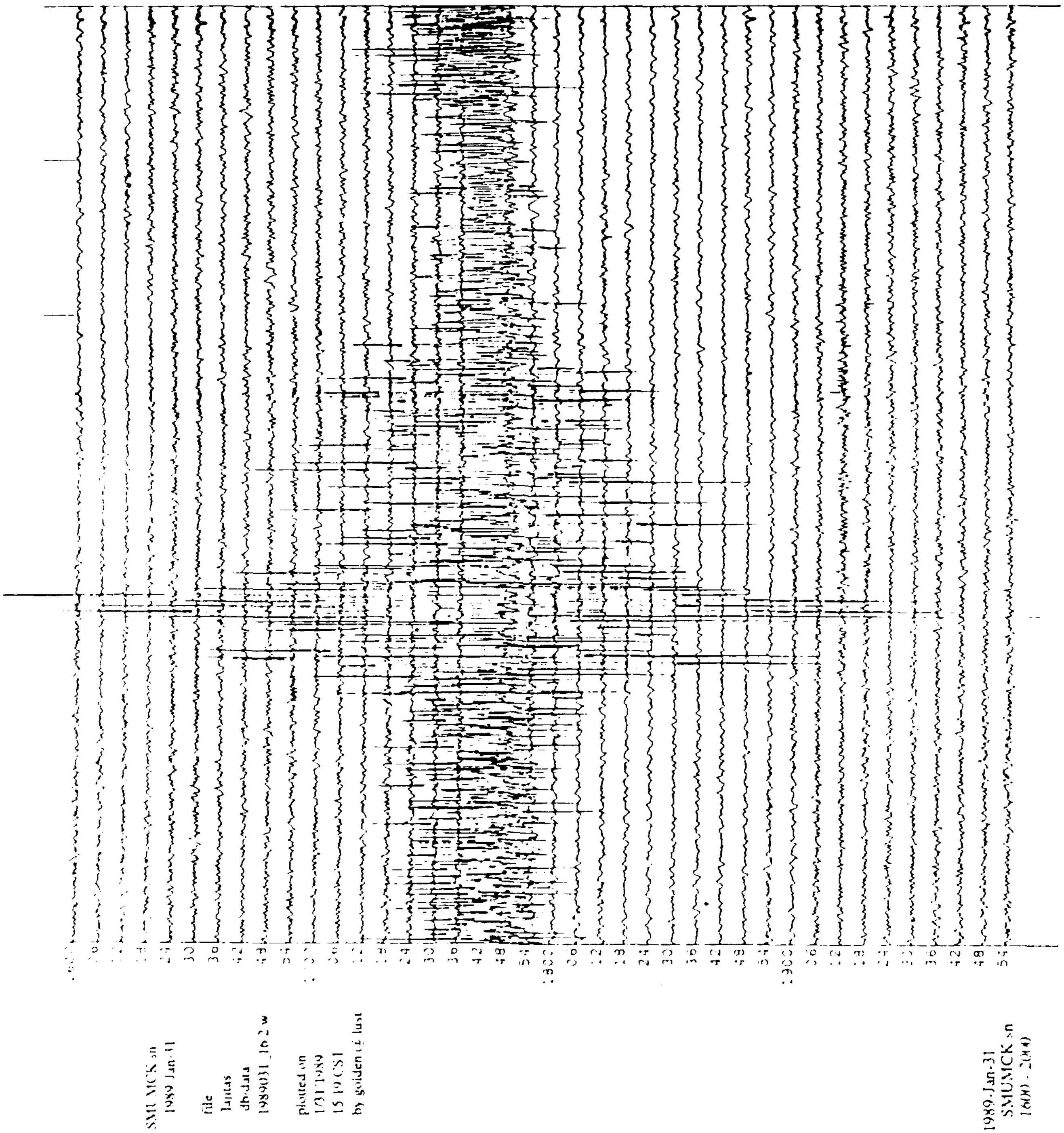

Figure 3.2. Four hour display of horizontal (N-S) short period data channel including noise and a regional earthquake, recorded at Lajitas TX.

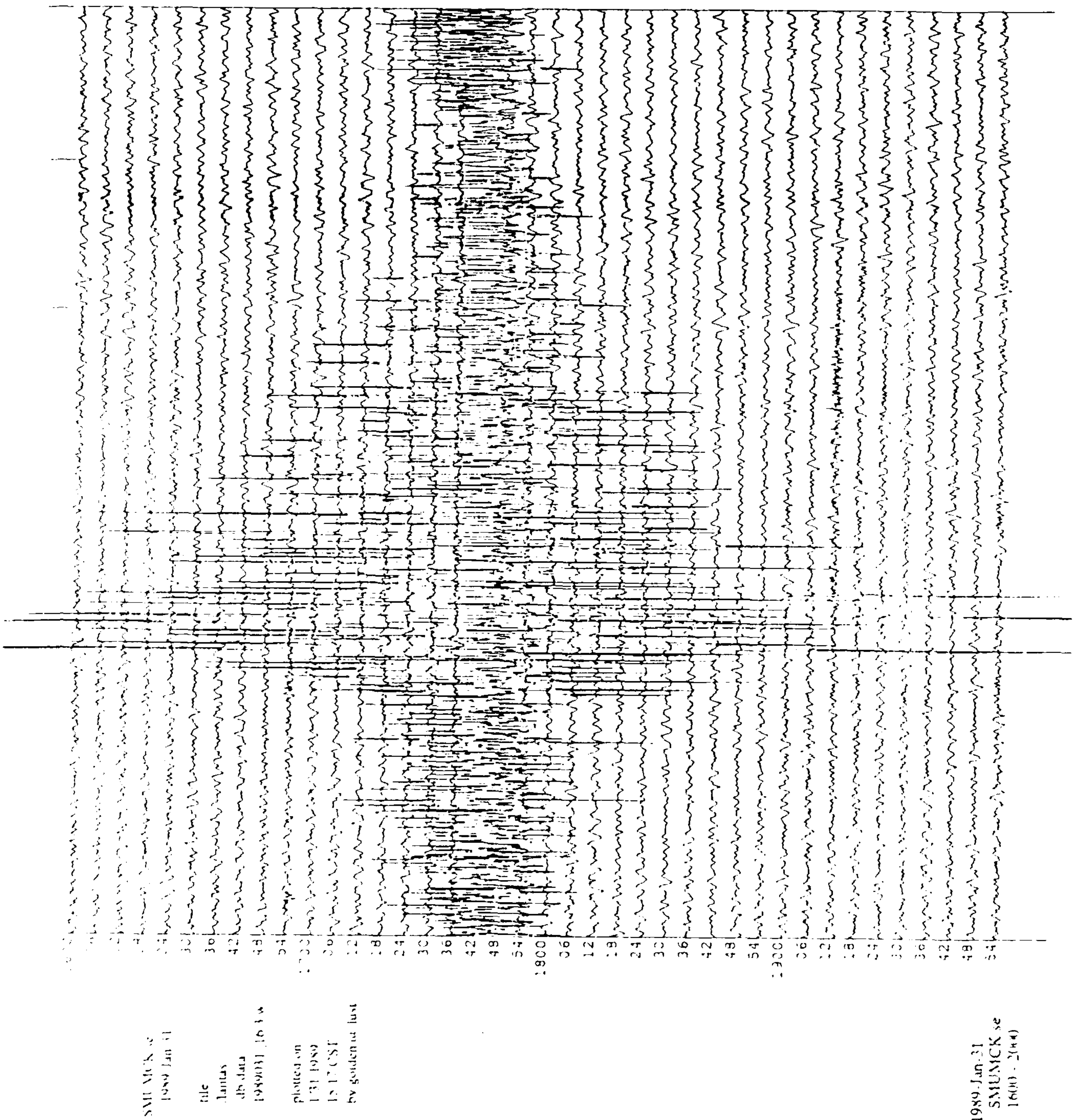

Figure 3.3. Four hour display of horizontal (E-W) short period data channel including noise and a regional earthquake, recorded at Lajitas TX.

allows the whole four hour data segment to be plotted on a standard Sun laser printer. In Figure 3.4, we show the twelve hour data segment of the vertical broad band channel for the same day. Because the broad band instruments are accelerometers, we integrate the time series (moving average) prior to plotting the data so that it appears as a velocity output. These hard copy displays are also useful to determine data quality and system status without having to assign an analyst to watch the real-time data stream on a full time basis.

Interesting Noise Data

The data in Figure 3.5 is from a relatively quiet period at the Lajitas station. Figure 3.6 shows the same type display of short period vertical data taken during a high noise period, however, the abrupt onset and cessation of the high noise 'bursts' led us to believe this was not normal cultural noise. In addition, Figure 3.7 shows the broad band vertical channel for the same time period illustrating that the noise is all high frequency. Figure 3.8 shows the spectra of normal background at Lajitas versus noise samples taken during this high noise period. It is clear that this unusually high noise would obliterate a small event. A phone call to a local resident in the Lajitas area verified that during the time period of this unusual noise, the highway department had been using road graders to clear debris from the shoulders of the highway. The distance from the station to the highway being graded, ranged from as far as ten kilometers to approximately three kilometers. The extreme noise caused by the road work illustrates how easily a seismic event could be masked by seemingly normal cultural events at an extremely quiet seismic station such as Lajitas.

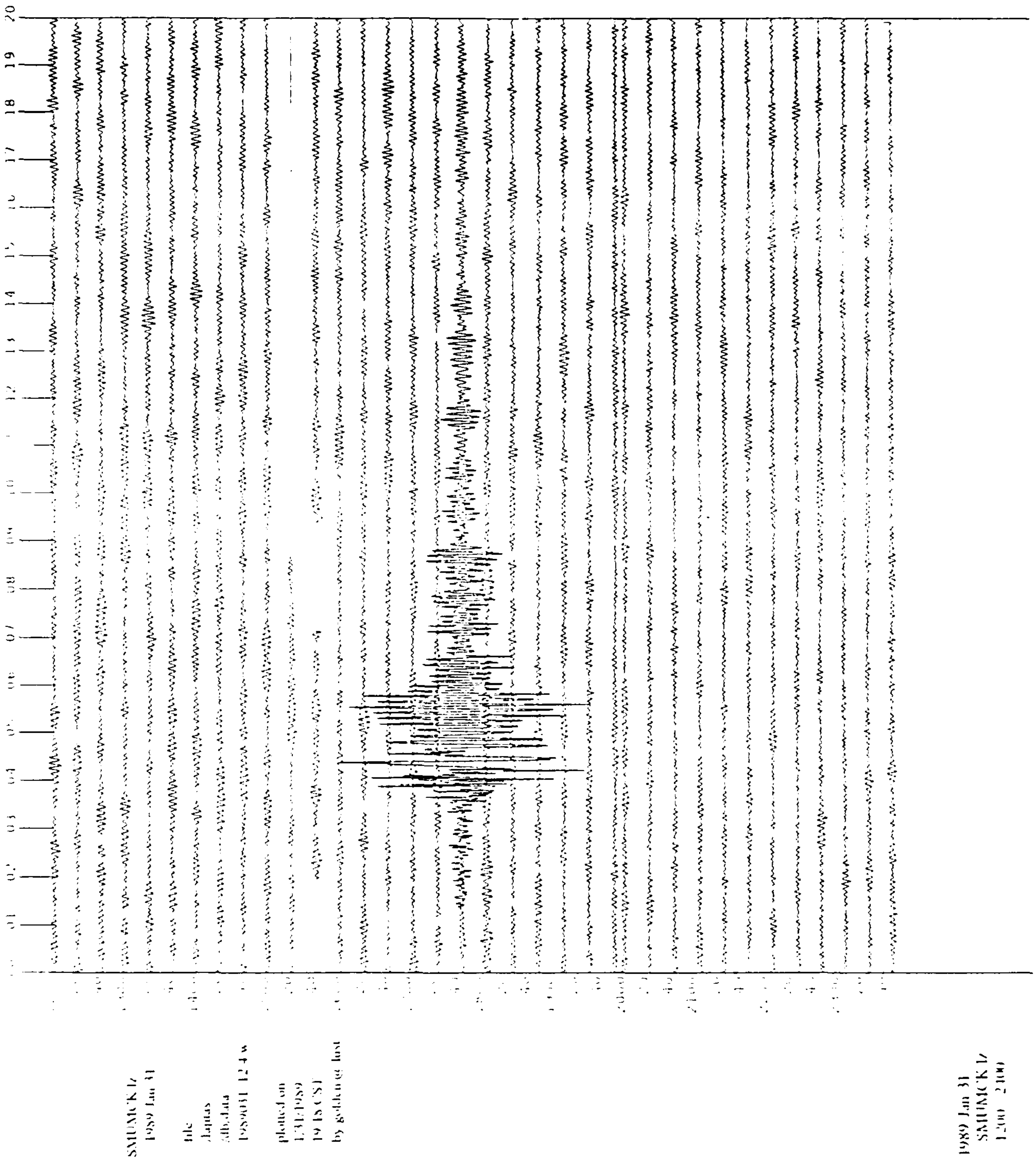

Figure 3.4. Twelve hour display of vertical broad band channel from Lajitas, TX showing integrated accelerometer output.

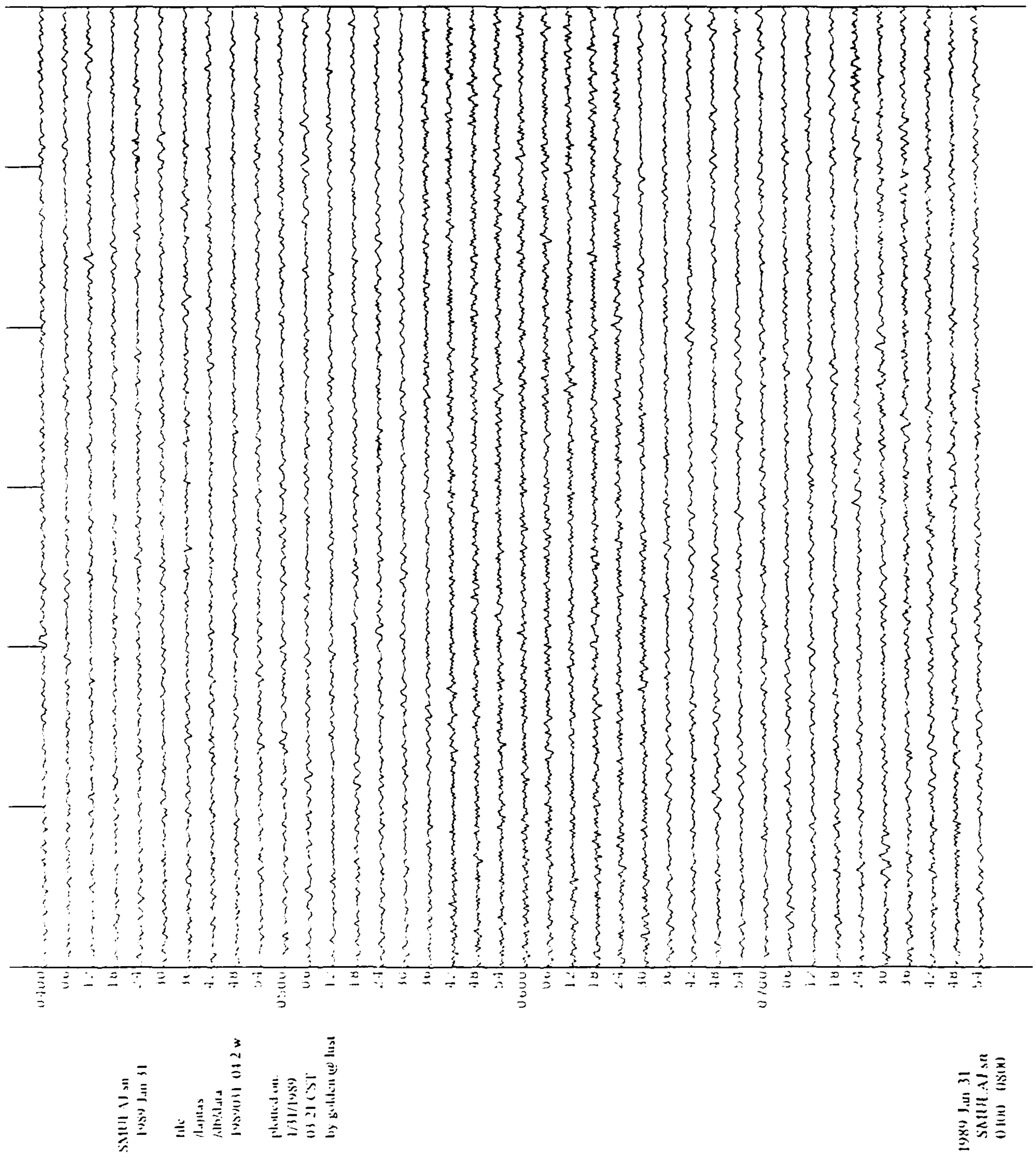

Figure 3.5. Four hour display of short period vertical channel from Lajitas, TX showing low noise conditions.

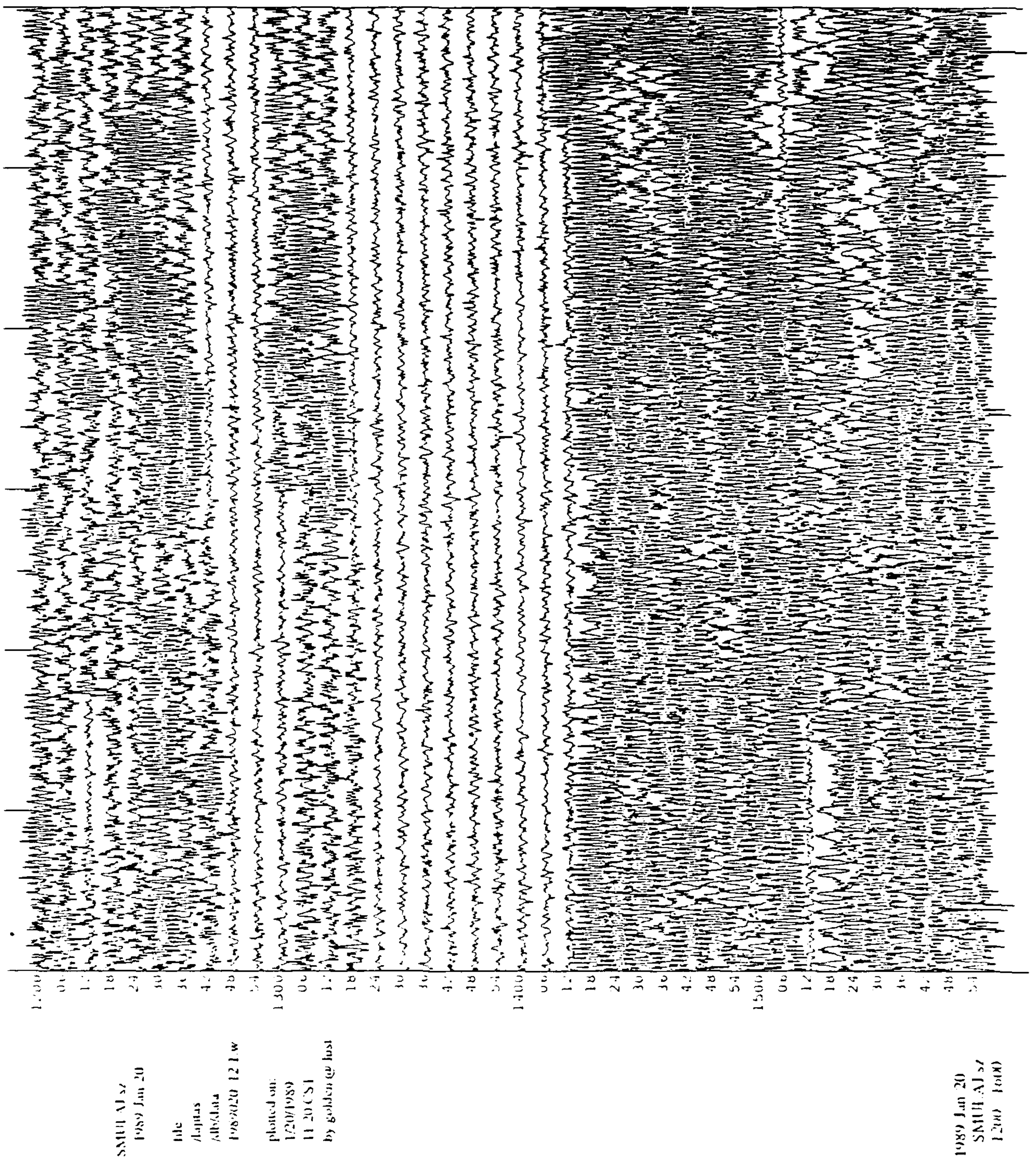

Figure 3.6. Four hour display of short period vertical channel from Lajitas, TX, during high noise conditions.

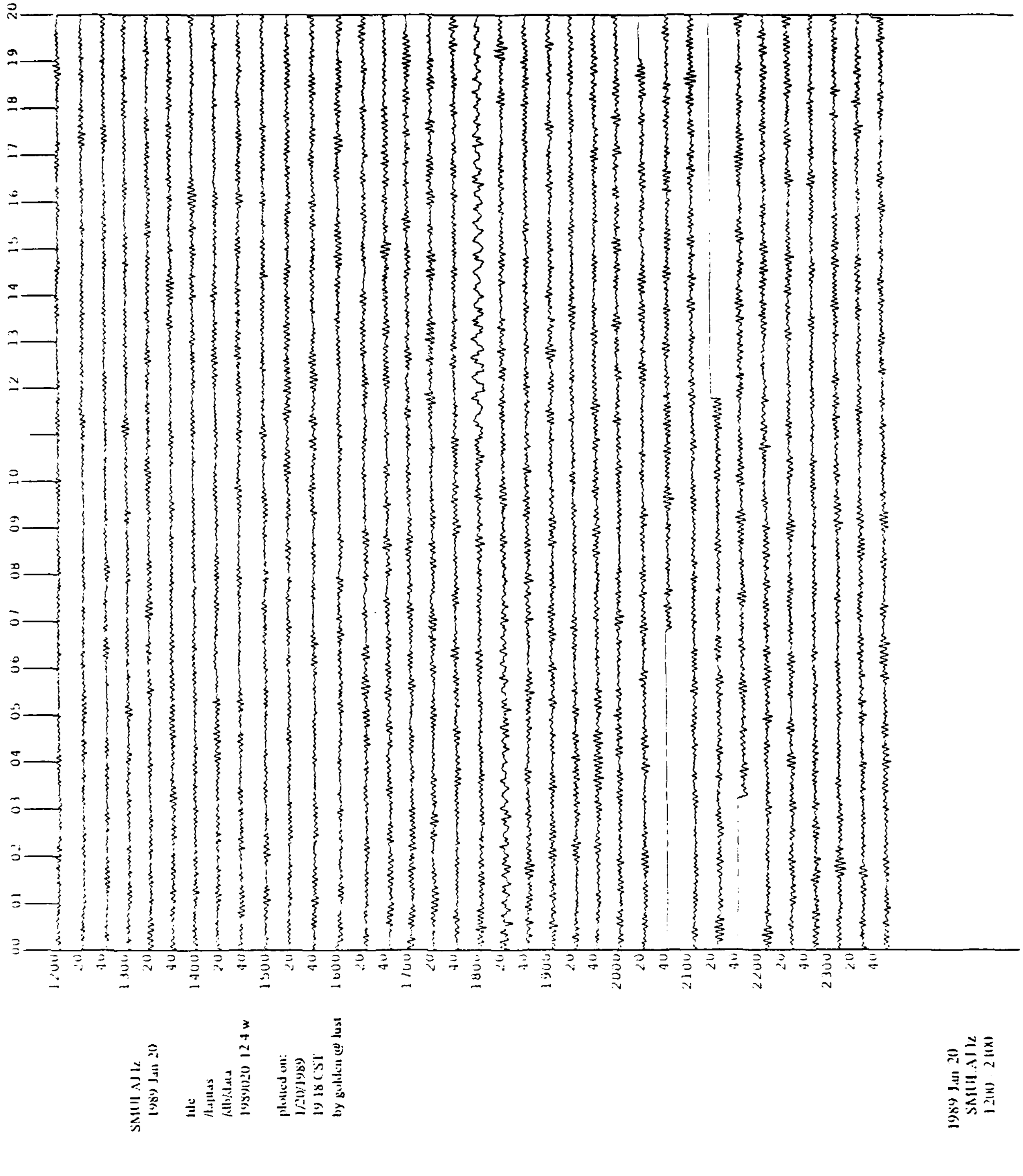

Figure 3.7. Twelve hour display of vertical broad band channel at Lajitas, TX encompassing same time period as in Figure 3.6.

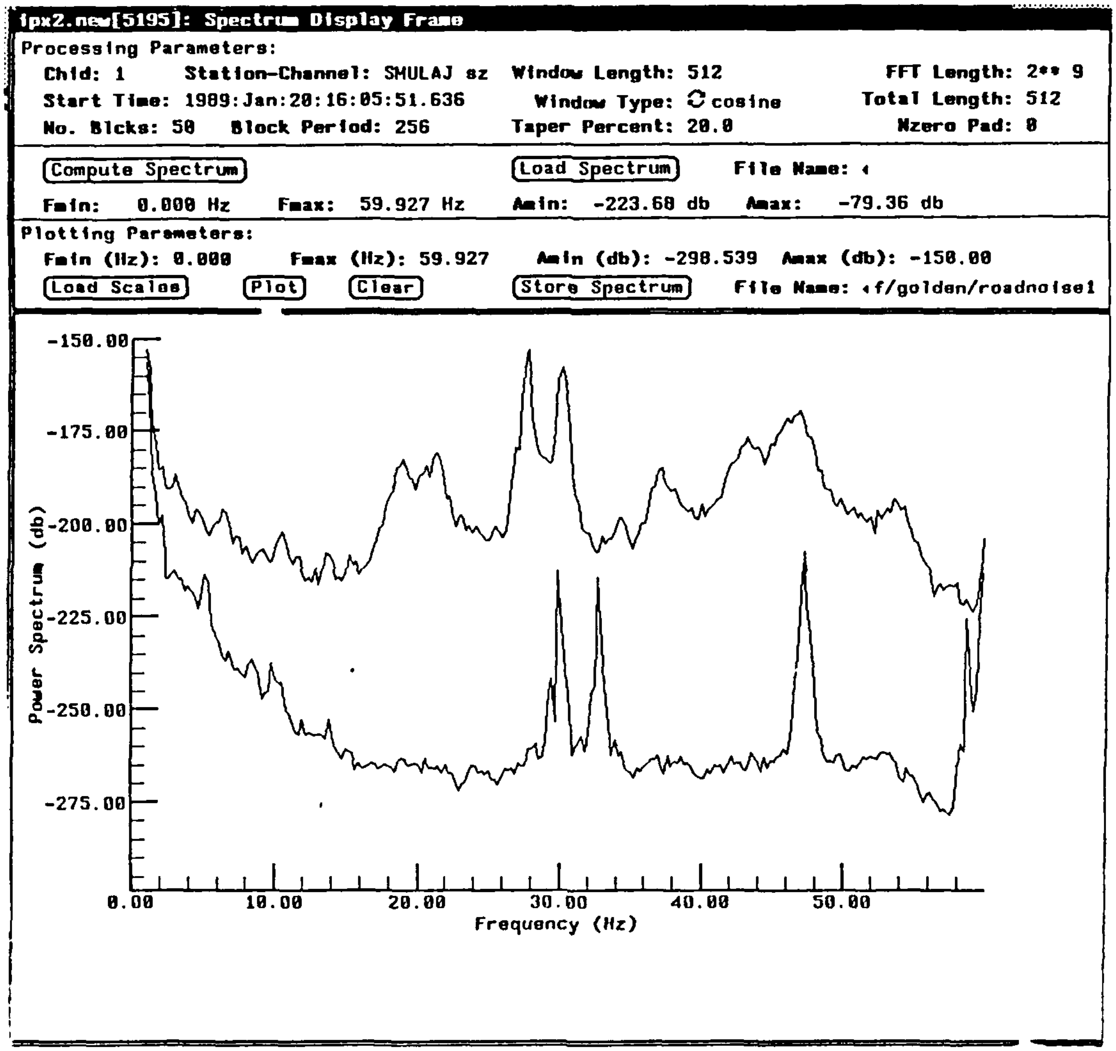

Figure 3.8. Block averaged spectra of quiet Lajitas background noise compared to high noise time period in Figure 3.6.

INTERESTING EVENTS

Several interesing events occurred during this reporting period. These include two nuclear tests at the Nevada Test Site, one on December 10, 1988 and the other on March 9, 1989; an earthquake at regional distance from Lajitas in Utah on January 30, 1989; a January 19, 1989 earthquake near Santa Monica Bay, CA; and the Armenia earthquake on December 7, 1988. These events will be shown along with results of some GSETT2 type analysis.

Underground Nuclear Tests at the Nevada Test Site

Figure 3.9 shows the three component short period seismograms of an underground nuclear explosion at the Nevada Test Site on December 10, 1988, at 203000.0 UTC, code named MISTY ECHO. The location of the event was 37.199n and 116.209w. This is a typical NTS test shot with an NEIC magnitude of 5.1. In Figure 3.10 we show the three-component short period seismograms of this event on an expanded time scale. In Figure 3.11 we expand the time scale again and increase the gain, and with some imagination, we begin to see what has become a characteristic precursor to the Pn arrival on the high resolution Lajitas data. However, in Figure 3.12 we have band pass filtered the data and now the precursor becomes more obvious, occurring approximately 1 second prior to the original Pn pick. In Figure 3.13 we have increased the gain again and made the time pick for the precursor, showing that it arrives 1.17 seconds before the original Pn start time. A Pn magnitude was calculated and yielded an Mb of 5.1 which is exactly the same as the NEIC reported magnitude. Using particle motion analysis on the first arrival, a back azimuth of 288 degrees was obtained just as in the case of many other NTS events, while the true great circle path is closer to 310 degrees. This evidence again suggests a high speed path exists south of

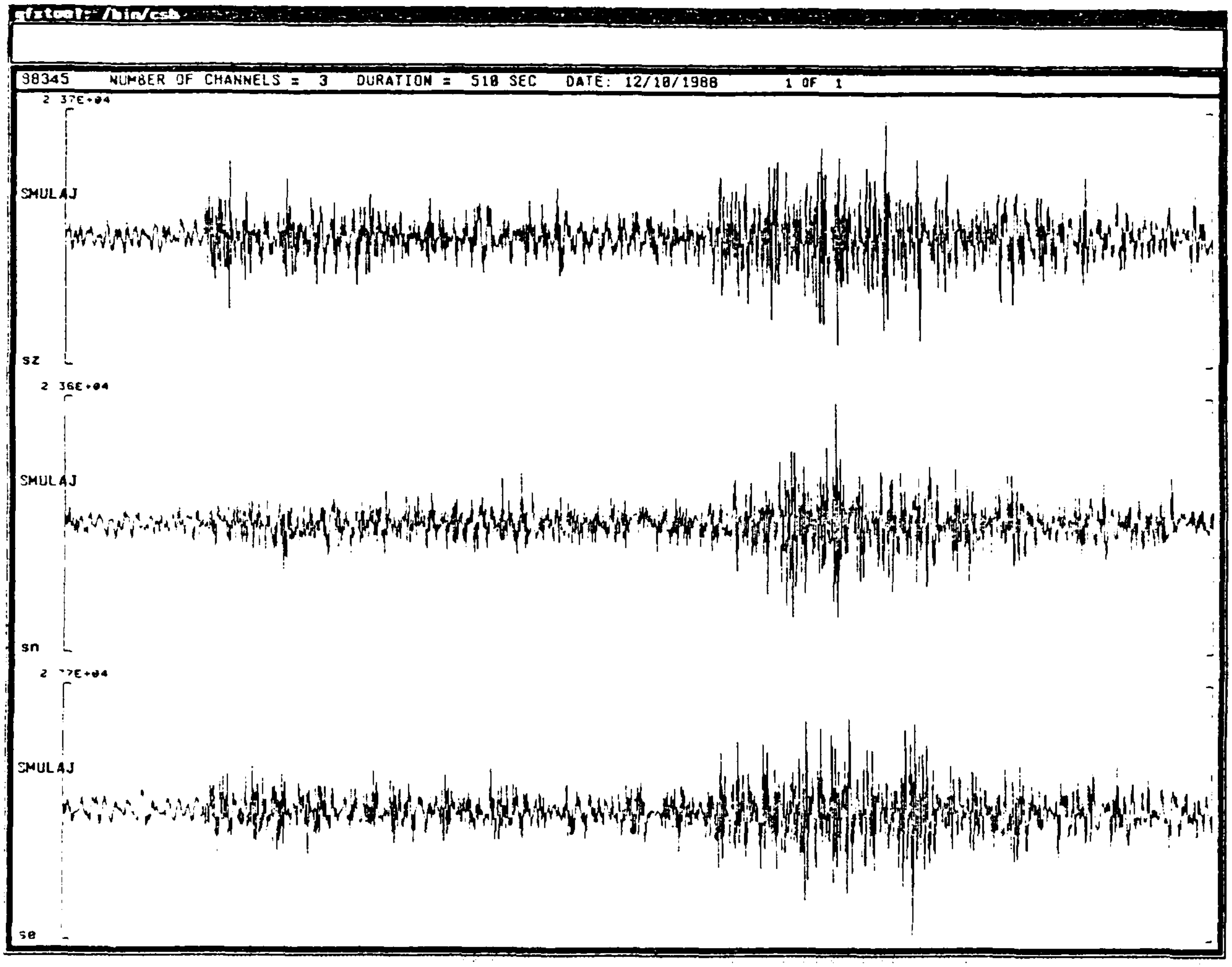

Figure 3.9. Three-component short period seismograms of underground nuclear explosion, MISTY ECHO,recorded at Lajitas, TX.

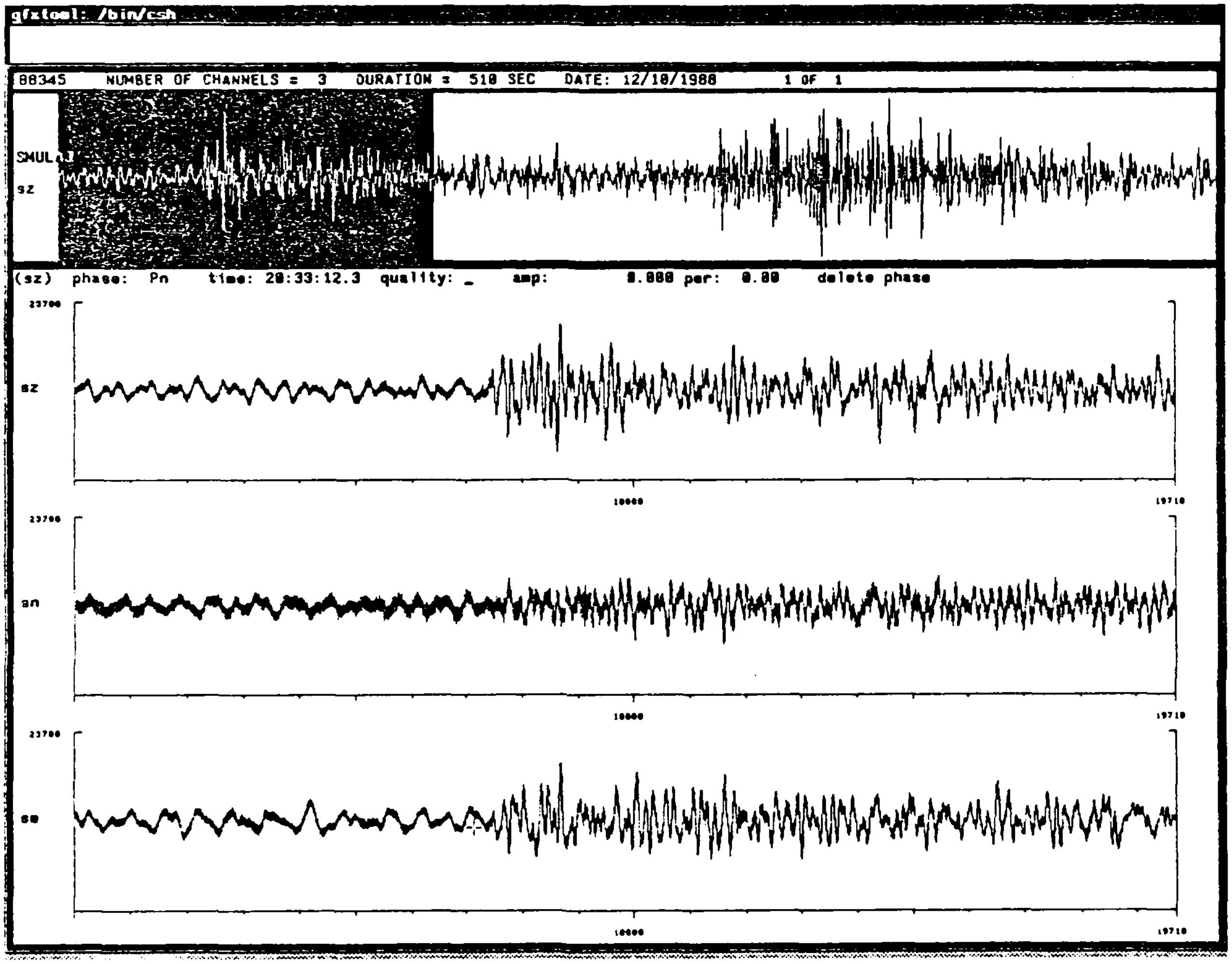

Figure 3.10. Three-component short period seismograms of MISTY ECHO shown on expanded time scale.

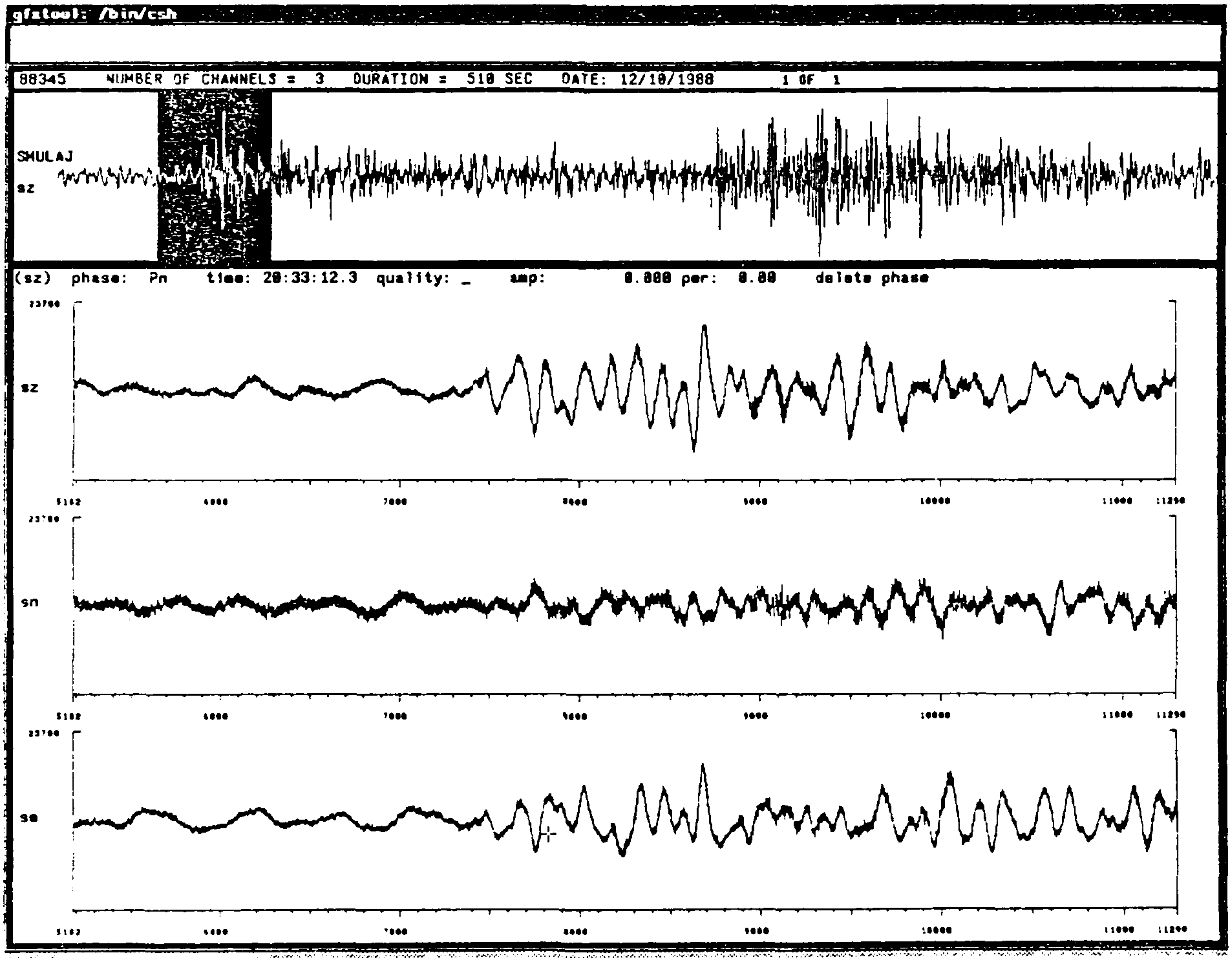

Figure 3.11. Three-component short period seismograms of MISTY ECHO shown on expanded time scale with increased gain.

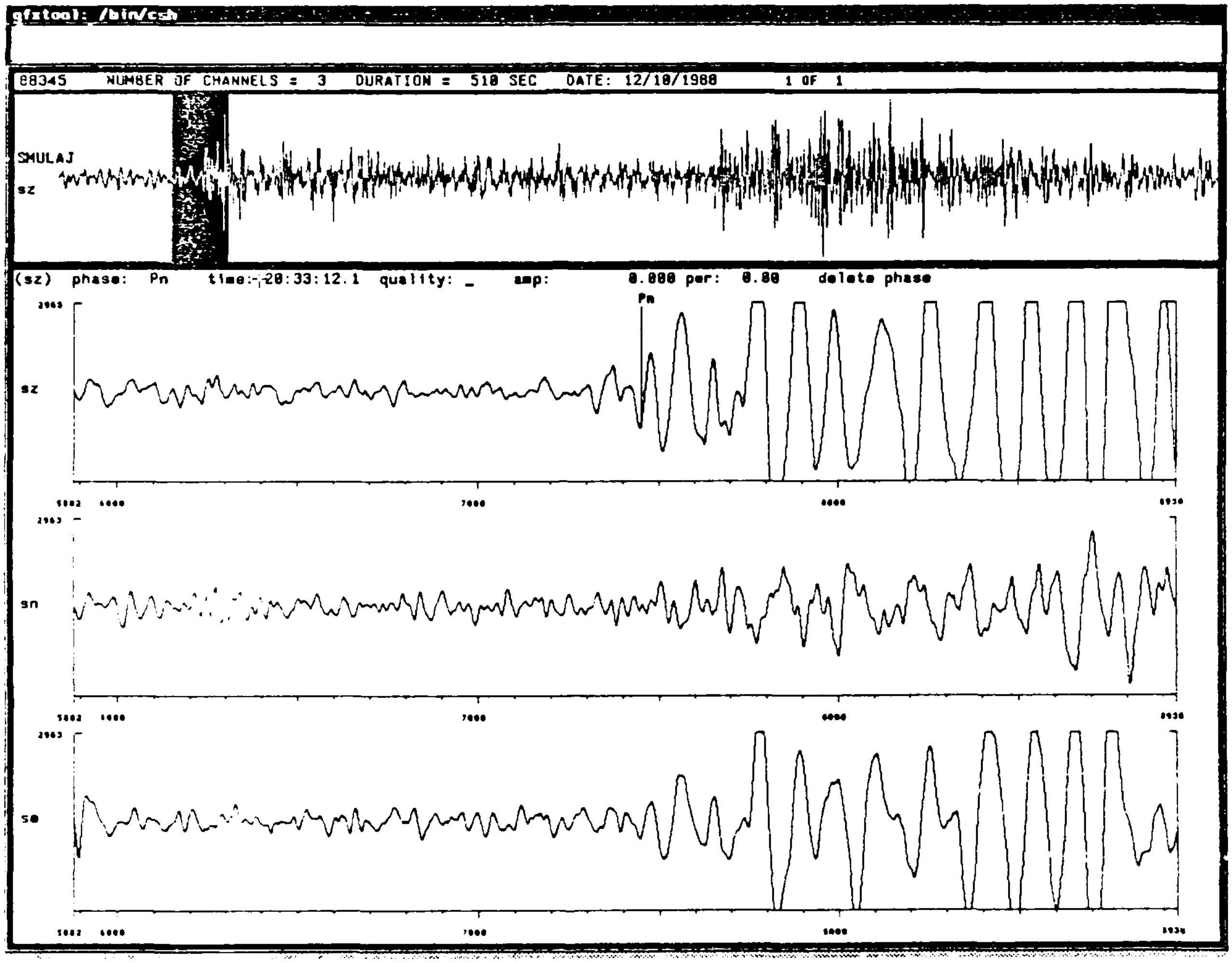

Figure 3.12. Three-component short period seismograms of MISTY ECHO after band pass filtering.

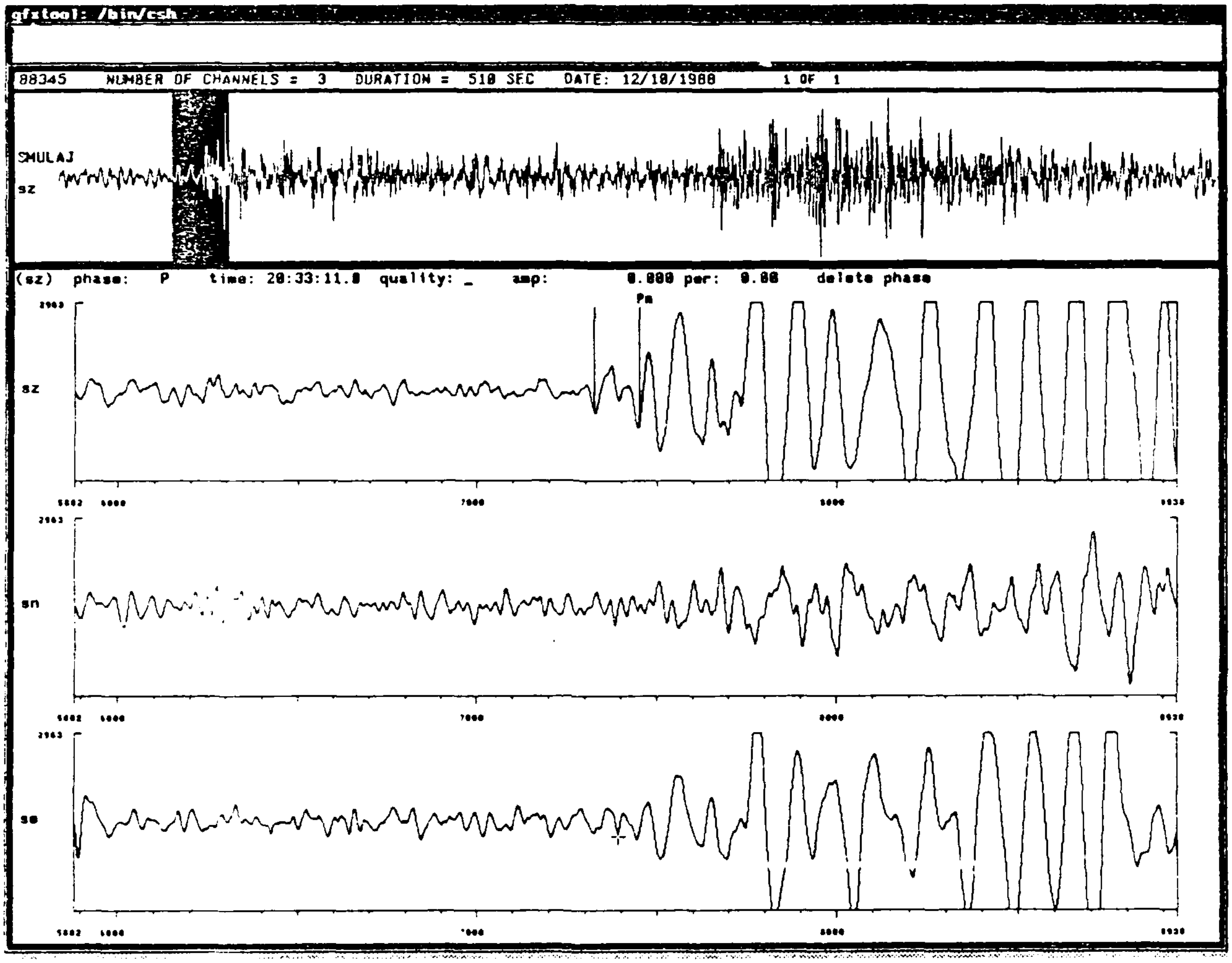

Figure 3.13. Three-component short period seismograms of MISTY ECHO after band pass filtering and increased gain.

the great circle route, along the U.S. Mexico border, or that anisotropic effects at the Lajitas station distort the wavefront.

Another NTS event was recorded at Lajitas , this one on March 9, 1989 at 140500.0 UTC, code named INGOT, located 37.143n and 116.067w, with an NEIC reported magnitude of 5.0. In Figure 3.14 we show the three component short period channels recorded at Lajitas for this event. Figure 3.15 shows the same channels displayed on an expanded time scale and higher gain. There is no obvious precursor to Pn shown on the seismogram. In Figure 3.16 we have band pass filtered the data as with previous events but still cannot see the precursor. Since this is the smallest NTS event we have used for our study, with a calculated magnitude of 4.9, we believe that the precursor is probably 'buried' in the noise, however, it could be caused by source location effects. Particle motion analysis of the first arrival yields a back azimuth of 285 degrees, which once again shows a travel path south of the great circle route, even though there is no obvious precursor. Experiments are being planned to help determine the cause of these observations.

Central Utah Earthquake

On January 30, 1989 an earthquake with NEIC reported magnitude of 5.0 occurred in central Utah with epicenter of 38.862n and 111.523w. The distance to Lajitas from the event is 1280 km with back azimuth of 327 degrees. The event is of interest because it was felt over a very large area of the western U.S., as well as the relative rarity of seismic events in Utah. In Figure 3.17 we show the three component short period seismograms of this event as recorded at Lajitas. The seismograms show the typical Pn and Lg arrivals from an earthquake at regional distance from the station. Figure 3.18

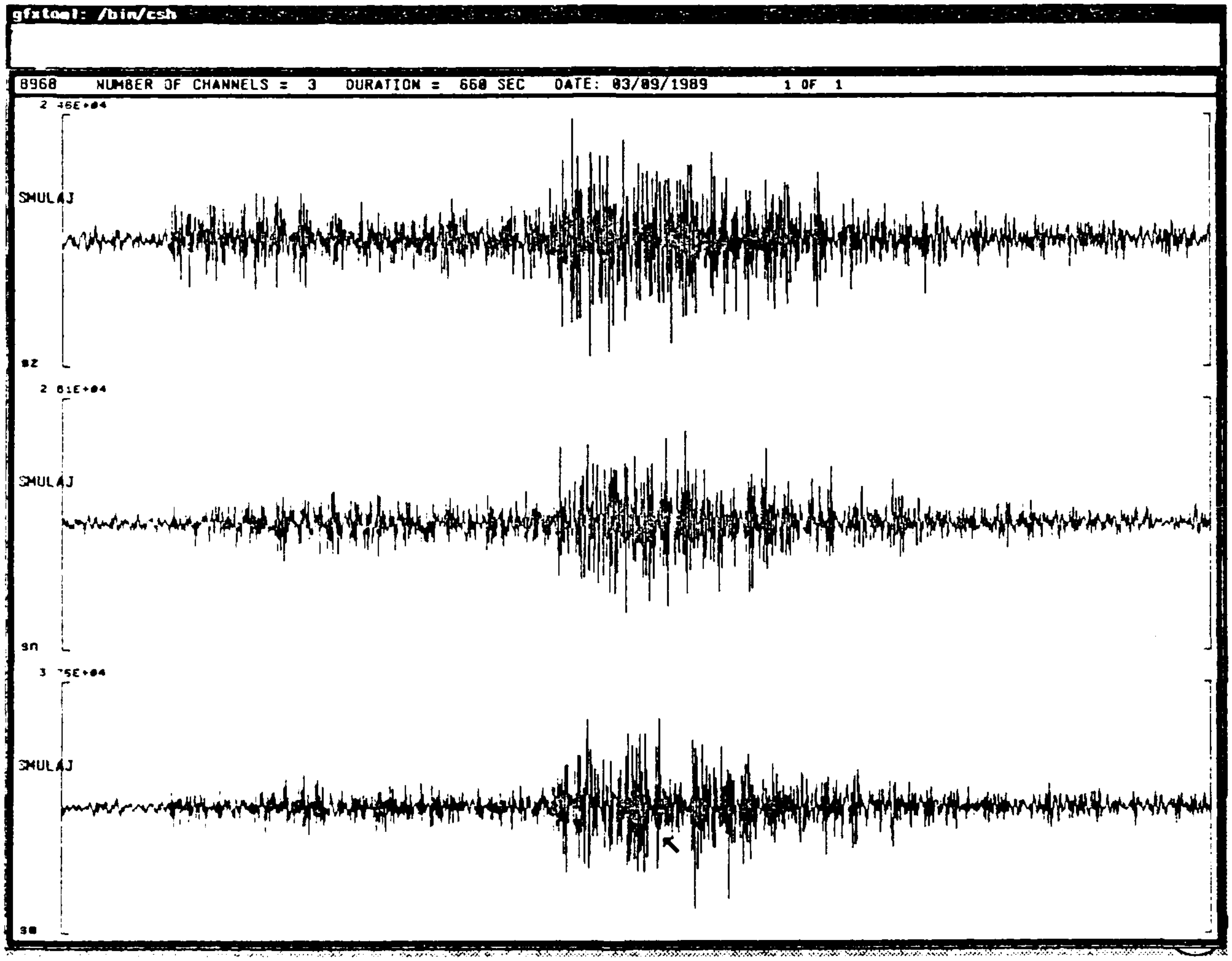

Figure 3.14. Three-component short period seismograms of underground nuclear explosion, INGOT, recorded at Lajitas, TX.

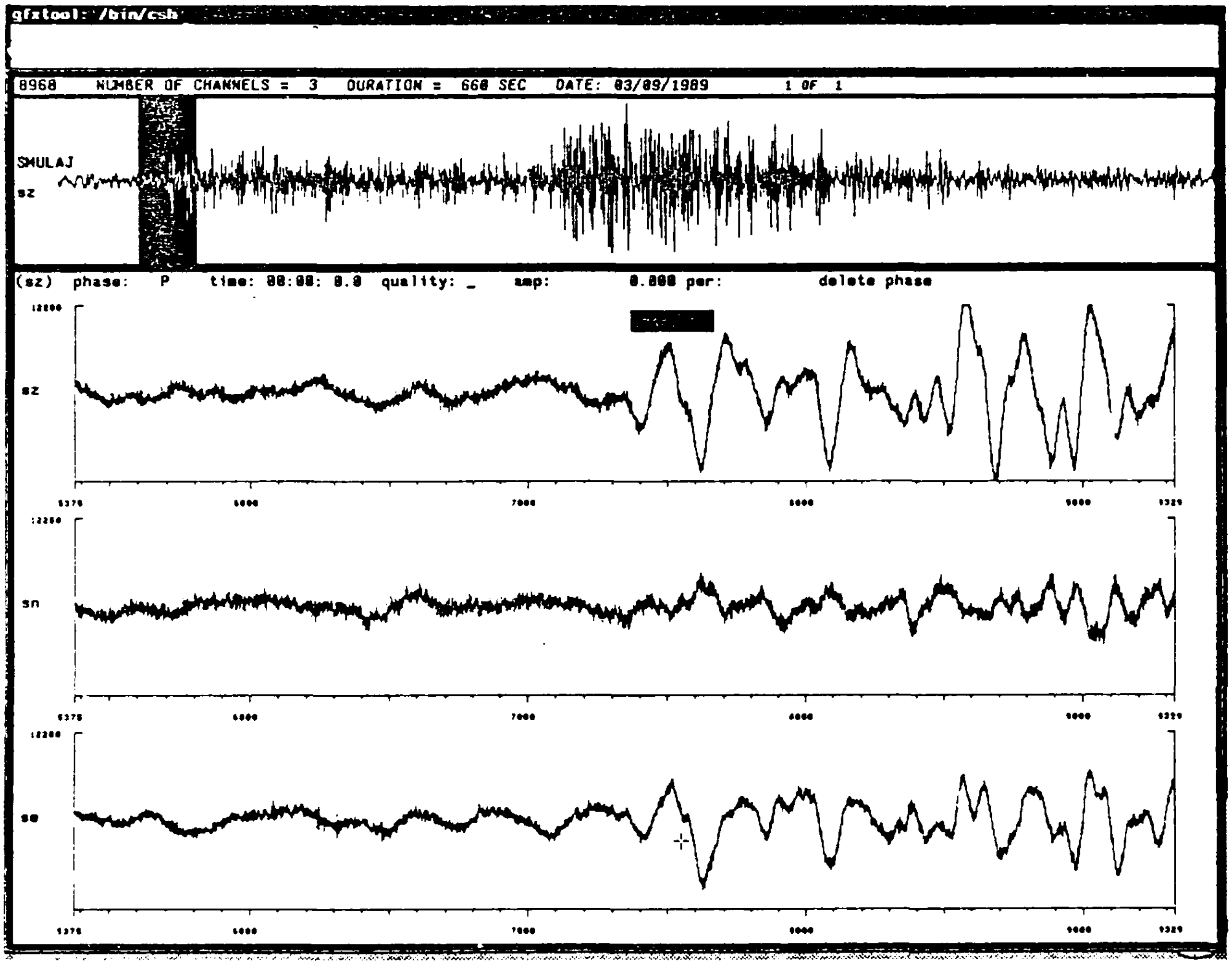

Figure 3.15. Three-component short period seismograms of INGOT shown on expanded time scale with increased gain.

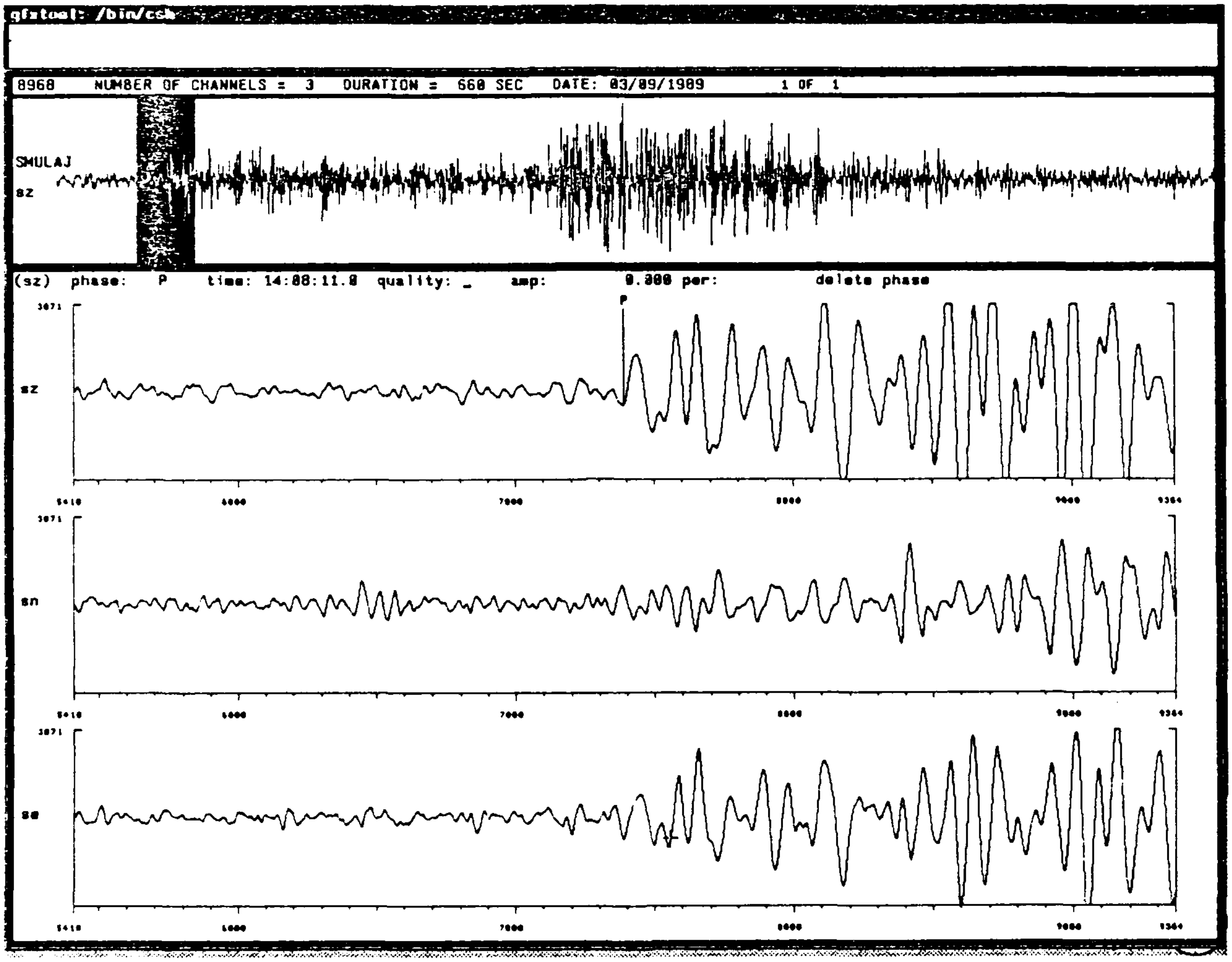

Figure 3.16. Three-component short period seismograms of INGOT after band pass filtering and increasing gain.

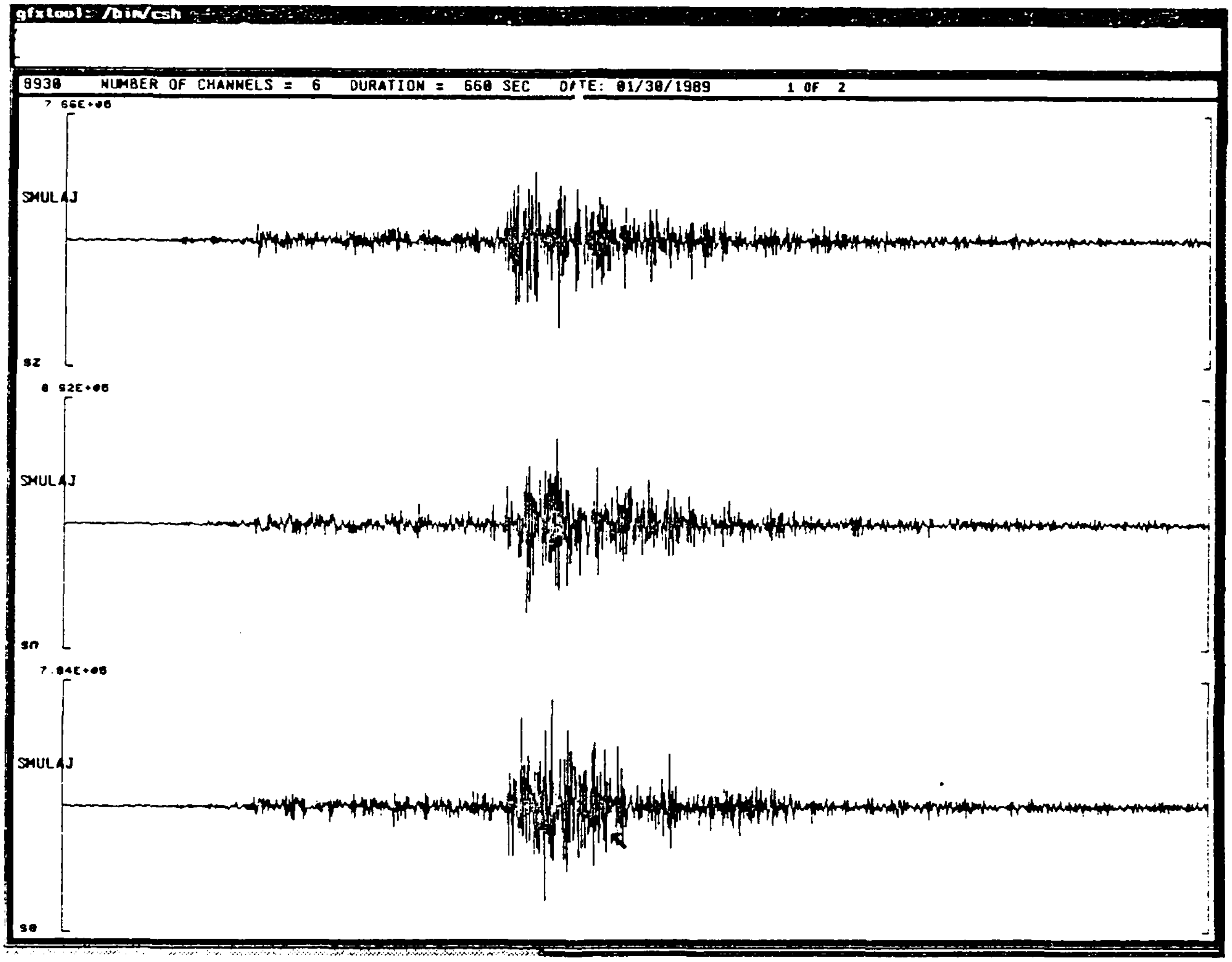

Figure 3.17. Three-component short period seismograms of an earthquake on January 30, 1989 in central Utah, recorded at Lajitas, TX.

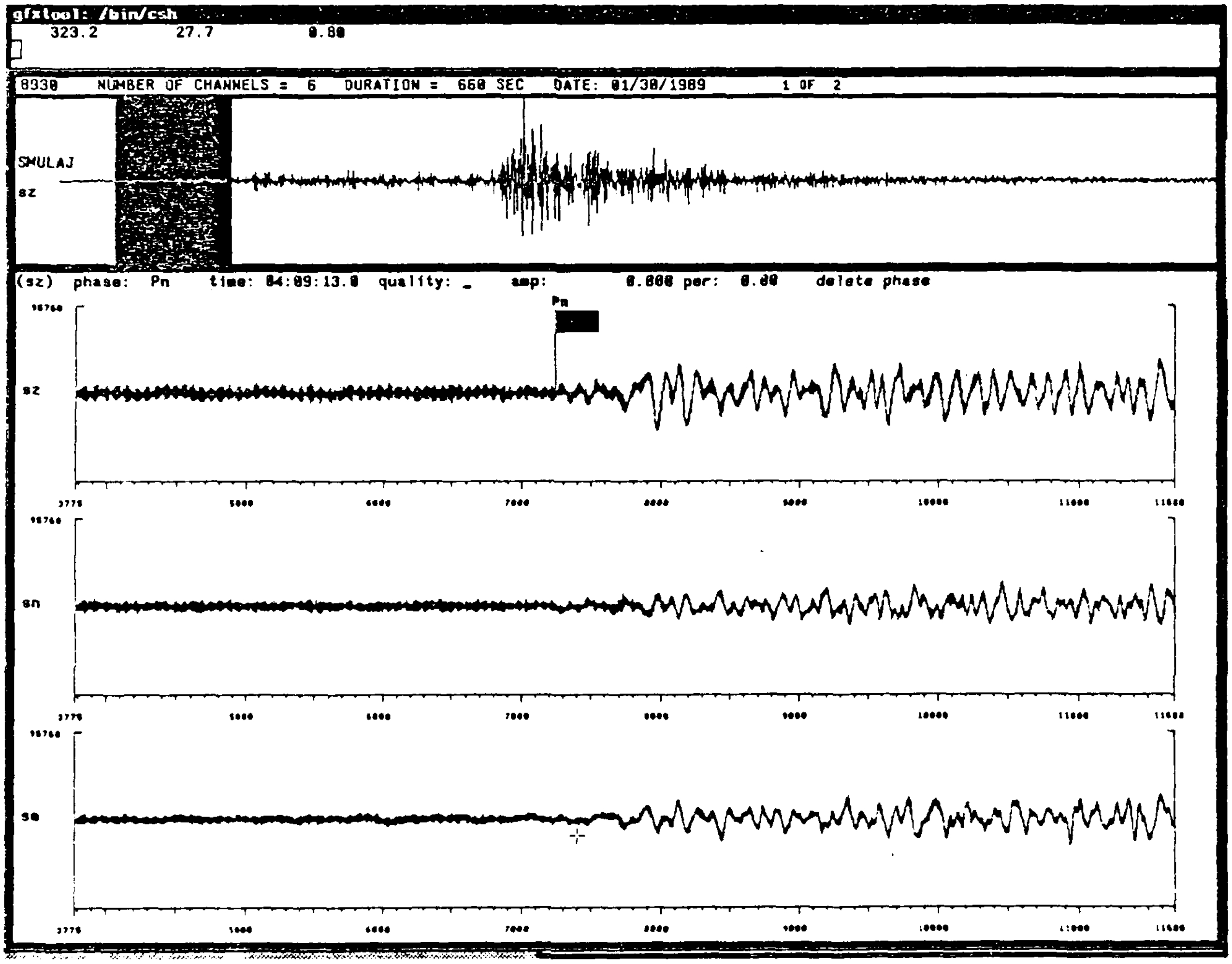

Figure 3.18. Three-component short period seismograms of central Utah earthquake, shown on expanded time scale.

shows the three component short period channels again but on an expanded time scale and centered only on the emergent Pn arrival. A back azimuth calculation yielded an estimate of 323.2 degrees which is in good agreement with the great circle path. Figure 3.19 shows the three component short period channels on an expanded time scale, but this time a band pass filter from 0.5 to 10.0 Hz was applied to the data. It is quite obvious that the first arrival is very emergent, due to source characteristics of the event. Another particle motion calculation was made on this emergent first arrival yielding a back azimuth estimate of 326.7 degrees, which is even closer to the true great circle path. In Figure 3.20 the unfiltered seismogram is shown again with the Pn arrival, chosen from the filtered data. This illustrates that the improvement in signal-to-noise from simple filtering has allowed a better determination of start time than would be obtained with the raw data, which was recorded on a windy day, evidenced by the high frequency noise on the seismograms.

Northern Armenia, USSR Earthquake

On December 7, 1988 an earthquake with a reported magnitude of 6.2 occurred in the northern Armenia area of the Soviet Union at latitude 44.941n and longitude 44.275e, a distance of 104.03 degrees from Lajitas. The NEIC Quick Epicenter Determinations estimated between 40,000 and 100,000 people were killed with the cities of Leninakan, Spitak and Kirovaken most severely affected. The event was felt throughout the Caucasus region of USSR, in large parts of northeastern Turkey and in the Tabriz-Orumiyeh area, Iran. In Figure 3.21 we show the three component short period seismograms of the Armenian earthquake at a scale as it would appear in near-real time on the SHI-Lodger monitor. In Figure 3.22, the three component short period

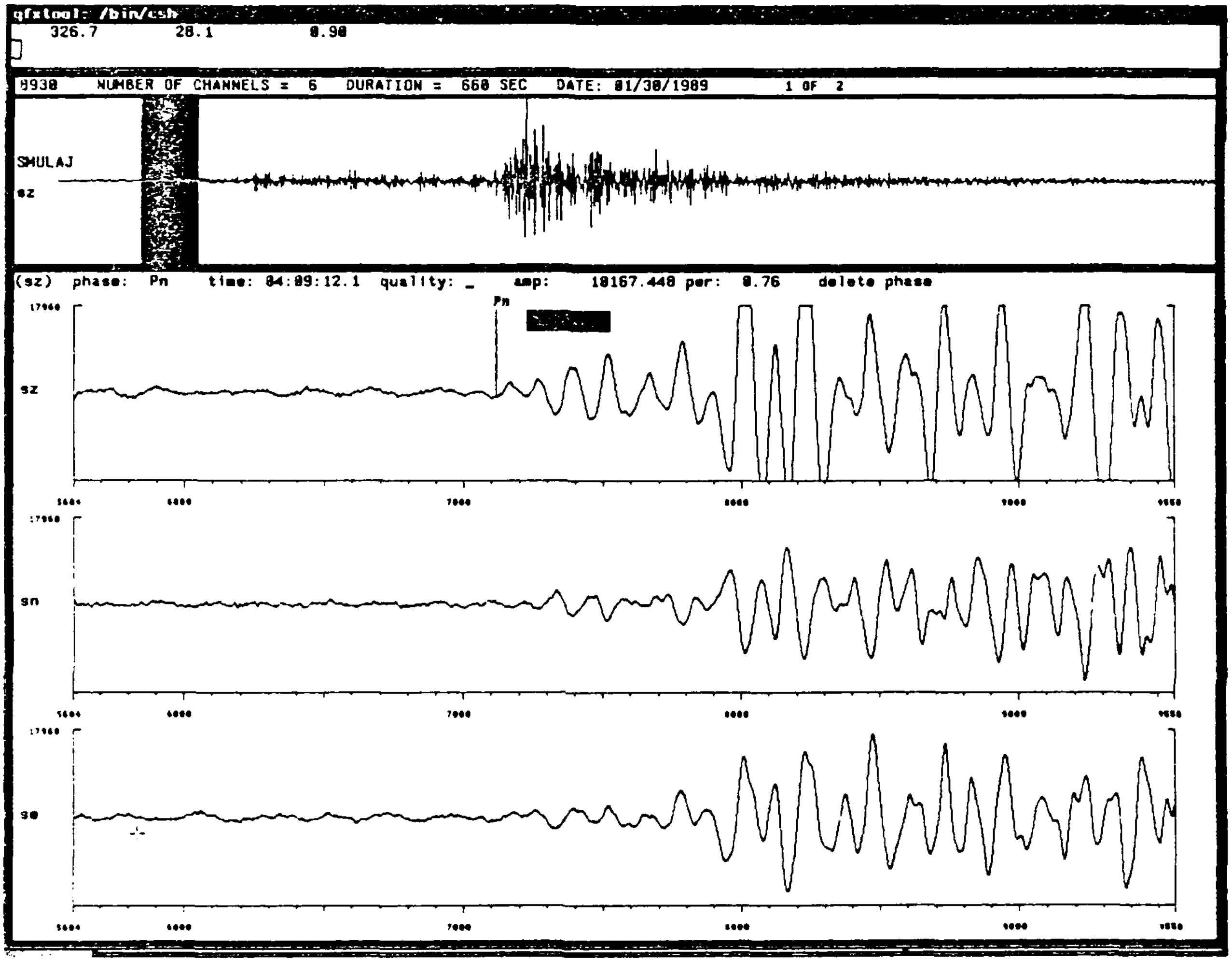

Figure 3.19. Three component short period seismograms of central Utah earthquake after band pass filtering.

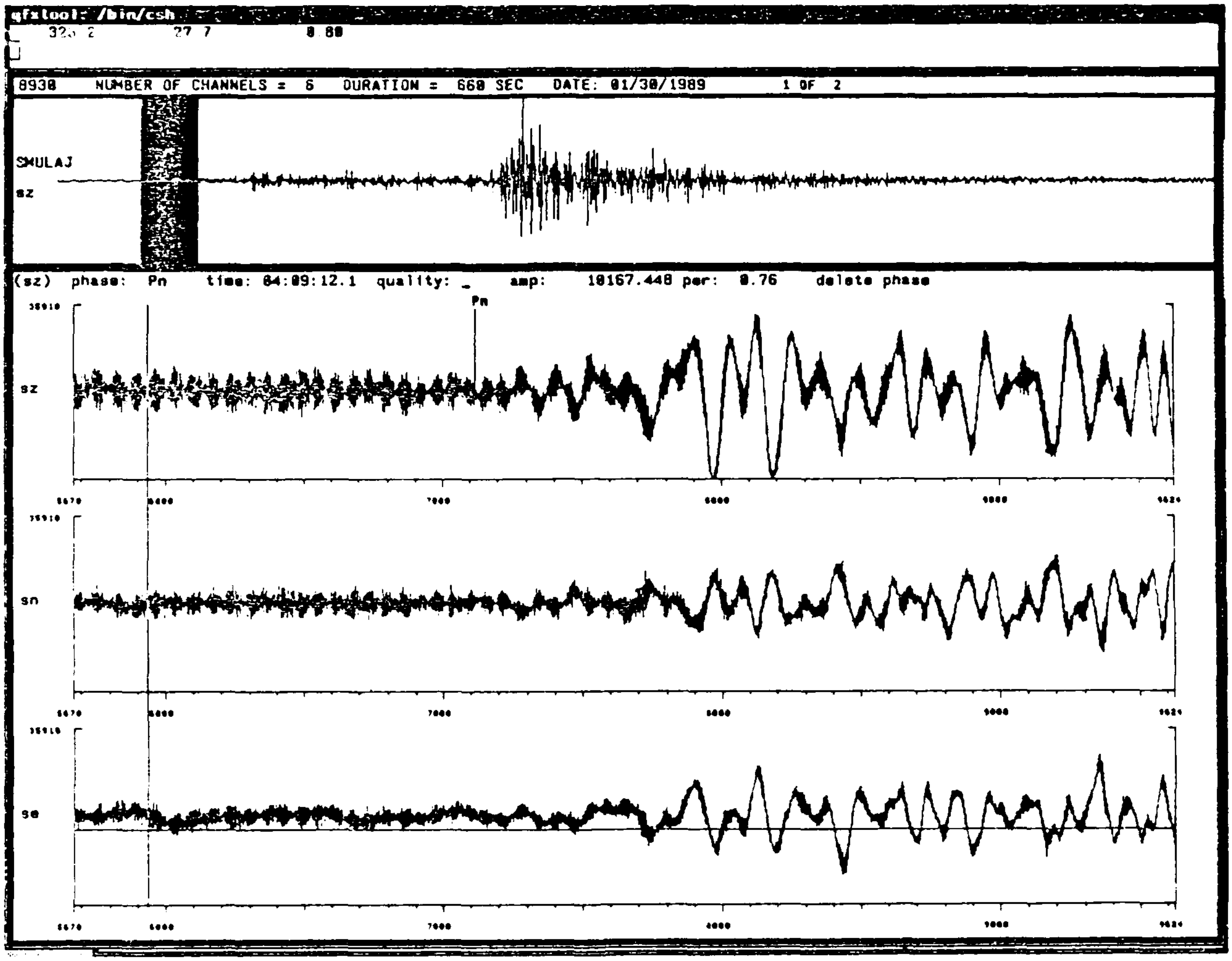

Figure 3.20. Unfiltered three component short period seismograms of Utah earthquake, showing Pn arrival time, picked from filtered data.

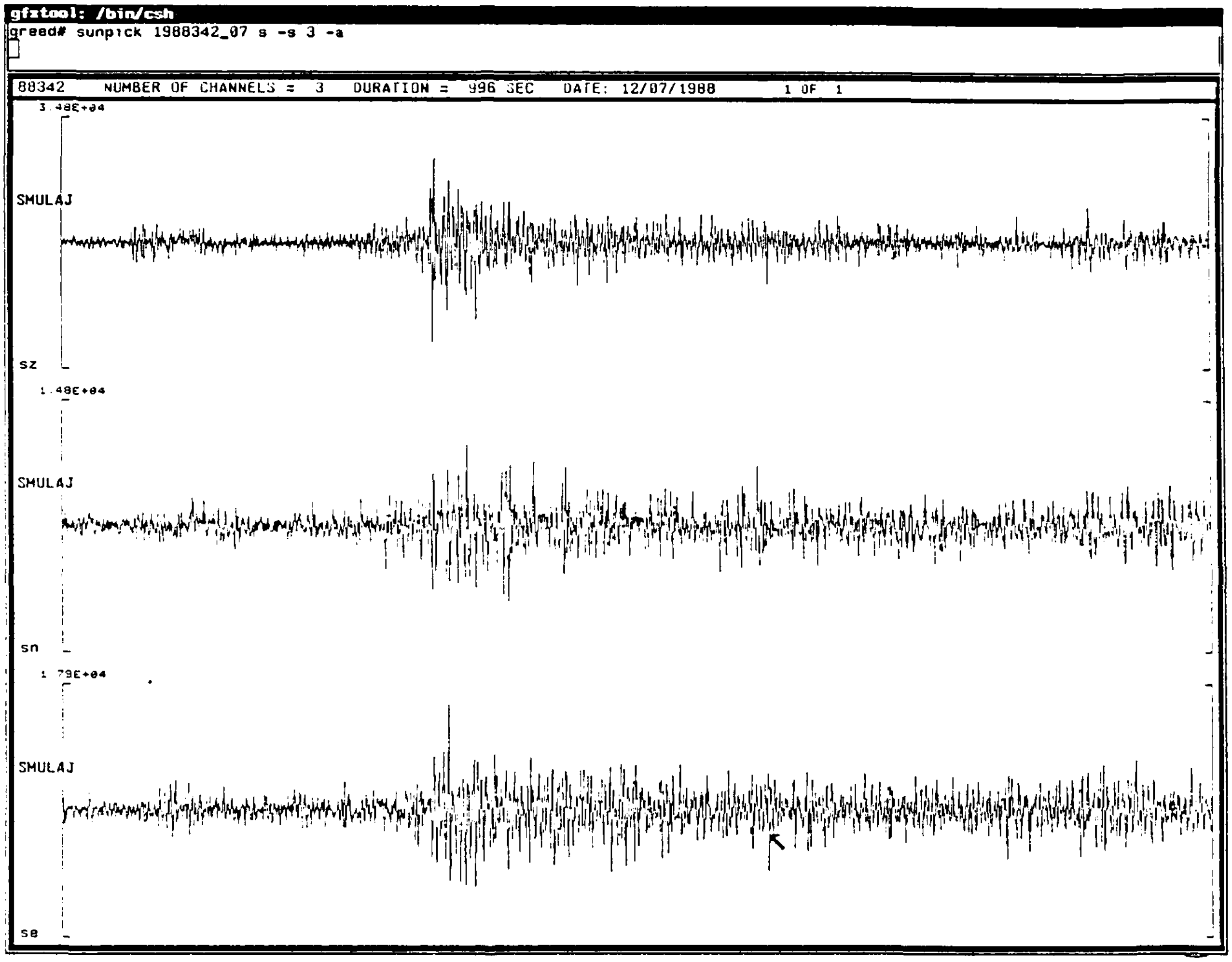

Figure 3.21. Three component short period seismograms of an earthquake on December 7, 1988, in northern Armenia, USSR, recorded at Lajitas, TX.

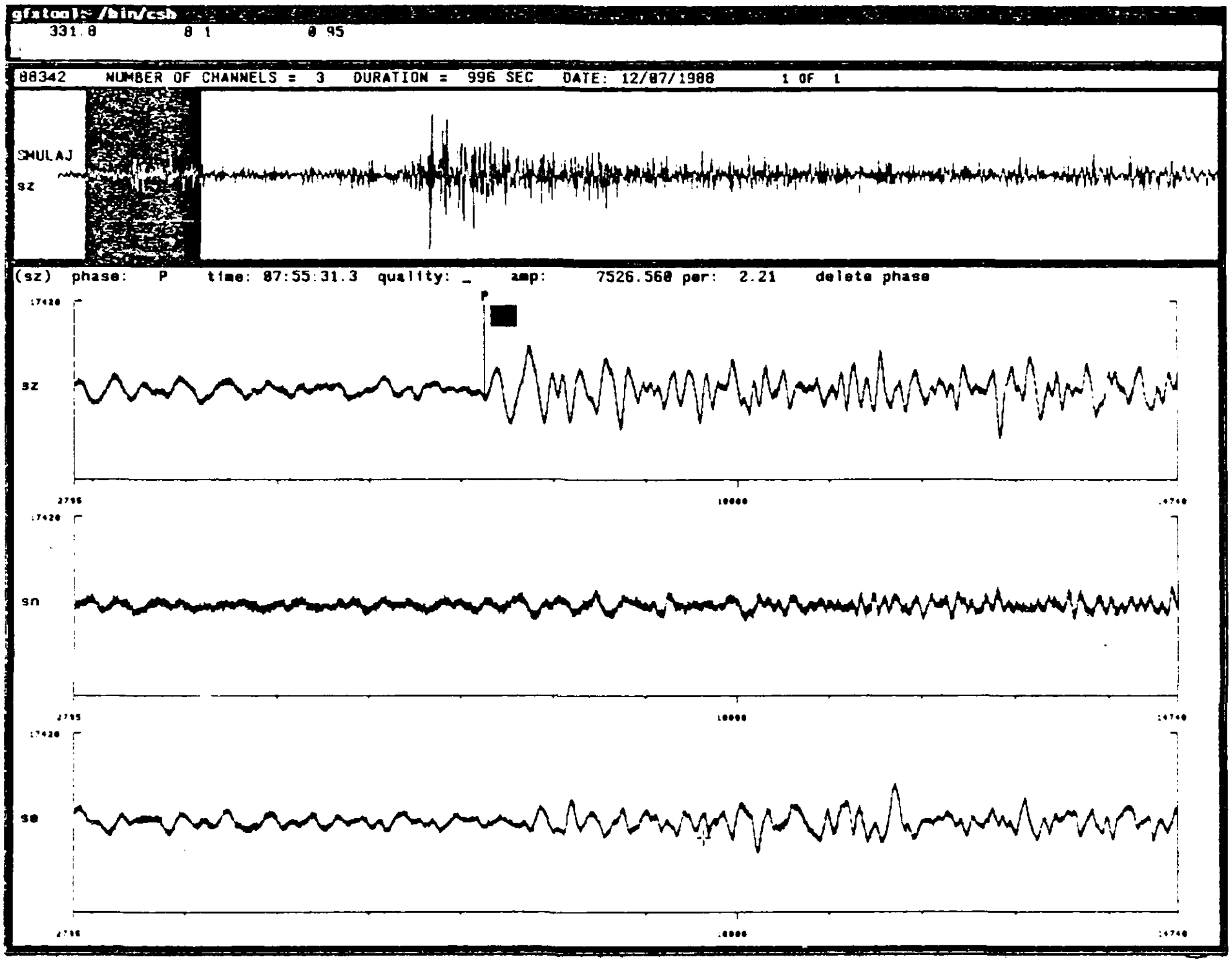

Figure 3.22. Three component short period seismograms of P wave arrival from the Armenian earthquake, shown on expanded time scale.

channels are shown again but on an expanded time scale to better illustrate the P arrival. Particle motion analysis on the P arrival yielded a back azimuth estimate of 331.8 degrees which is in good agreement with the great circle path of 331.4 degrees. The incidence angle was measured at 8.1 degrees and polarization was 0.95, all calculated relatively accurately because of the good signal to noise ratio of the large teleseismic event. A magnitude of 5.9 was calculated at the Lajitas station, which is smaller than the NEIC reported magnitude, probably because of the effect of the distance involved (in the shadow zone) and the diffraction of the P wave along the core boundary.

Santa Monica Bay, CA Earthquake

An earthquake of reported magnitude 5.2 occured just off the coast of southern California, southeast of Santa Cruz Island near the Santa Monica Bay area. The epicenter was reported to be latitude 33.922n and longitude 118.629w, with origin time 065328.0 UTC on January 19, 1989. The Quick Epicenter Determination reported some minor damage in the Malibu area and the event was felt throughout Los Angeles and as far as Santa Barbara. Figure 3.23 shows the three component short period seismograms of the event from Lajitas. The seismograms show a typical regional event with Pn and Lg arrivals dominating. A magnitude of 5.3 was calculated for the Lajitas station, which is only slightly higher than the NEIC reported magnitude. Figure 3.24 shows the short period channels from Lajitas on an expanded time scale, centered on the Pn arrival. Particle motion analysis gives a backazimuth estimate of 281.3 degrees while the true back azimuth is 293.5 degrees, indicating a travel path south of the great circle route could have been taken in this case also. Attempts at filtering to observe a precursor to this event were unsuccessful. The observation of a travel path south of the

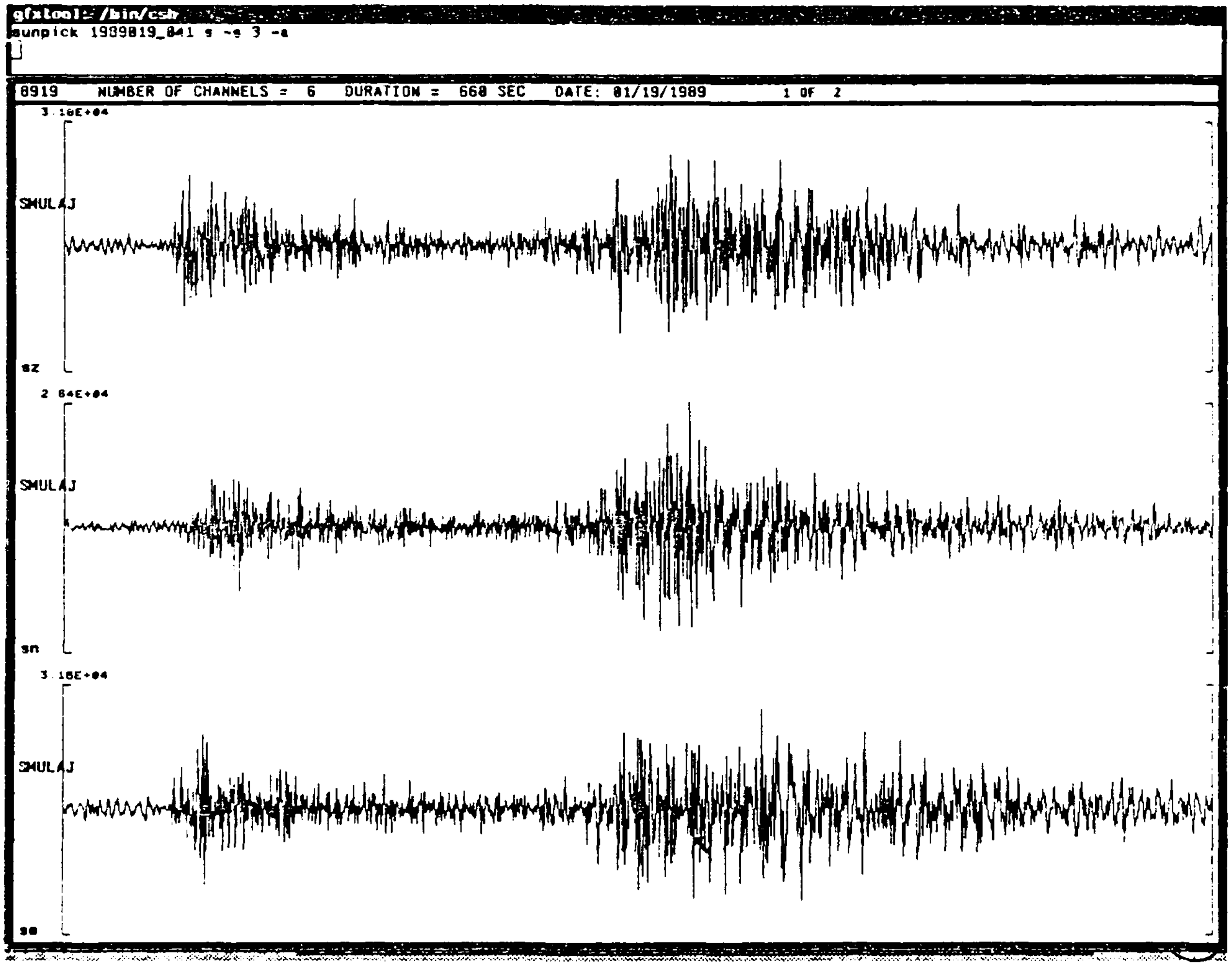

Figure 3.23. Three component short period seismograms of an earthquake on January 19, 1989 off the coast of southern California, recorded at Lajitas, TX.

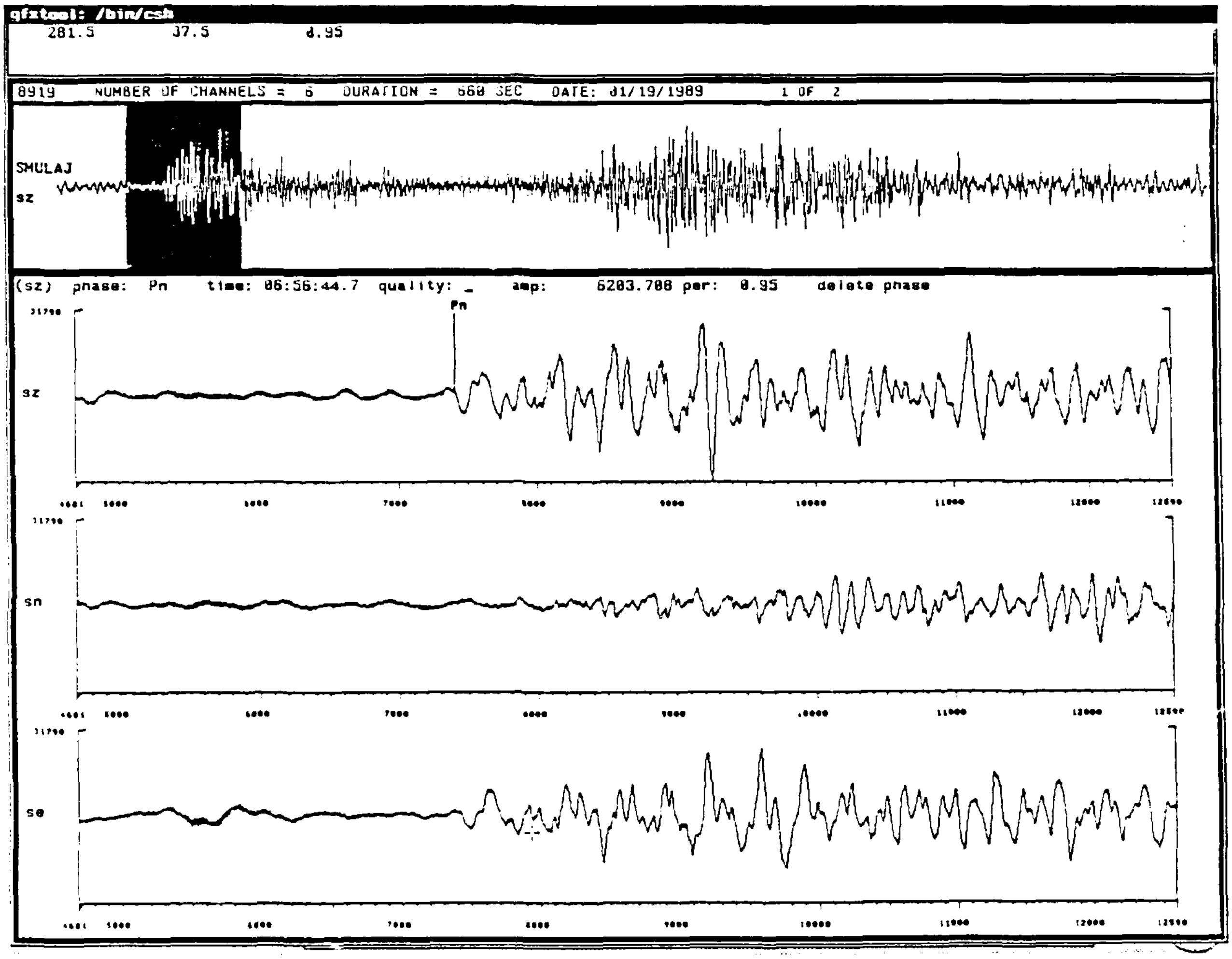

Figure 3.24. Three component short period seismograms of Pn arrival from the Santa Monica Bay earthquake, shown on expanded time scale.

great circle path but the lack of a precursor to the event could indicate that the cause of these observations are not directly related to each other or to the Lajitas station itself. However, without good constraints on the source mechanism of the event, no absolute conclusions can be made. In addition, since the precursor was not seen in one of the explosions from NTS, it could be caused by site effects at NTS, but much more data should be analyzed to better understand this phenomenon.

CONCLUSIONS

The SMU effort during this reporting period has been directed toward developing the Phase II systems for use in GSETT2 experiments and in planning for deploying the USGSE seismic network for participation in these experiments. In addition, the operation of the Lajitas seismic station and distributed NDC at Dallas has proved beneficial to the development of a functional NDC. This report has described the USGSE network in general and the Lajitas station in particular, including the complete instrument responses for both short period and broad band channels of the system. In addition the background noise characteristics of the Lajitas station have been briefly discussed.

The normal operations of the Lajitas seismic station and distributed NDC include acquisition and archiving of all seismic data on a regular basis. Though the station is not considered fully operational, because of ongoing research and development programs, most data is recorded. Events interesting to researchers or the general public are analyzed with various software packages, as much for the analysis as for examining the existing software packages. Several events were recorded and analyzed during this reporting period, and a few have been shown.

Functional requirements for the data acquisition modules of the Phase II seismic systems were presented along with requirements for some elements of the third generation, NORESS type array to be deployed in Europe. These requirements are considered to be working documents between SMU/DARPA and the major suppliers, Teledyne Geotech and Science Horizons Inc., and will be modified when necessary in order to provide a sytem that will perform as required. These systems will be deployed at the USGSE network sites during the summer of 1989.

The current schedule in preparing for participation in the GSETT2 experiments calls for deployment of the six USGSE seismic stations, four distributed NDC's, a data concentrator/archive facility and NDC central in Washington DC, in the summer of 1989 and be fully operational by October 1, 1989.